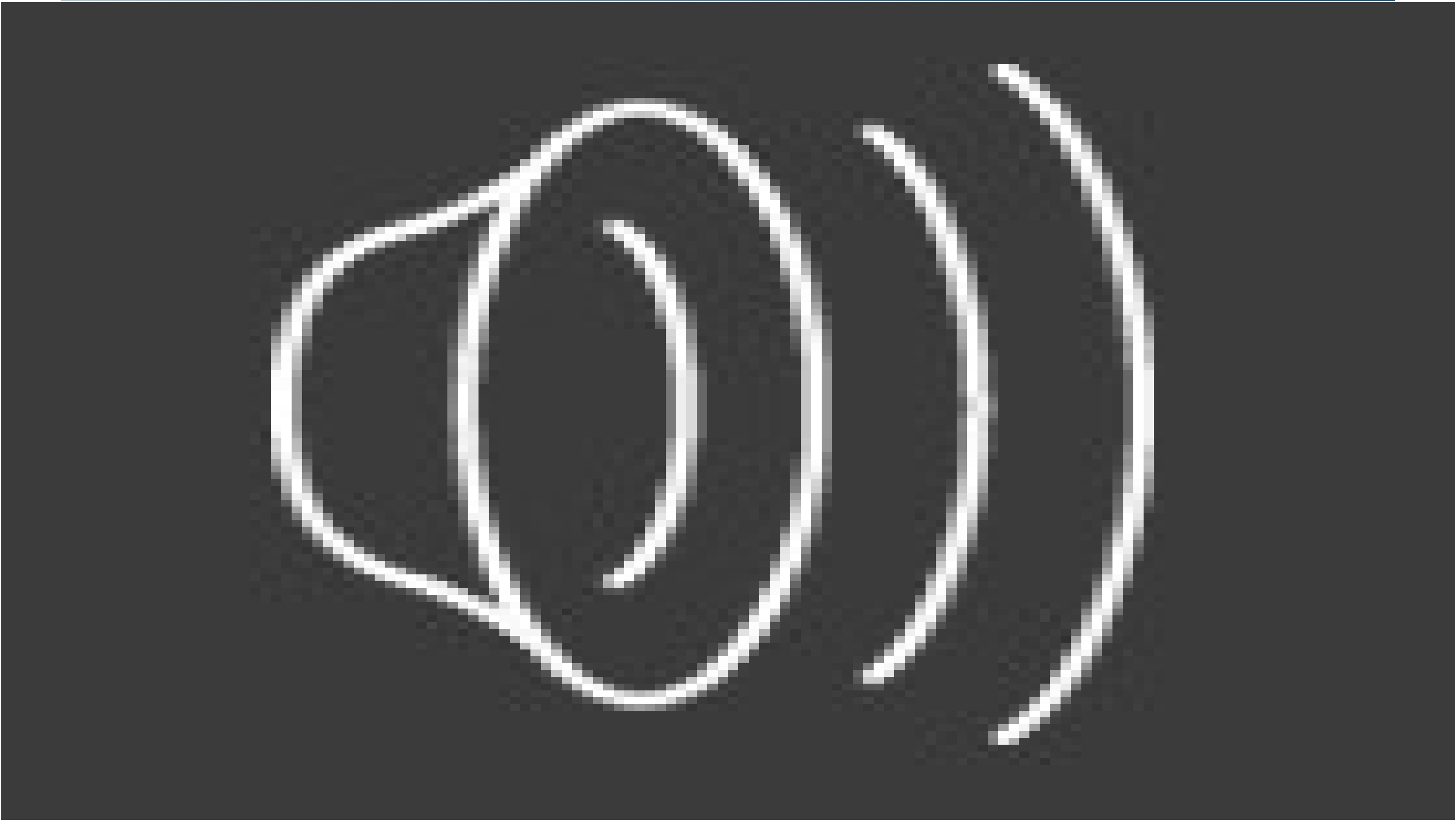
Welcome to
Defense Advanced Research Projects Agency (DARPA)
Tactical Technology Office (TTO)
Proposers Day

April 20-21, 2016

TTO Highlights



Tactical Technology Office

Dr. Bradford C. Tousley, Director
DARPA Tactical Technology Office

Briefing prepared for TTO Proposers Day

April 20-21, 2016

Mission

The Defense Advanced Research Projects Agency (DARPA) was established in 1958 to **prevent strategic surprise** from negatively affecting U.S. national security and **create strategic surprise** for U.S. adversaries by maintaining the technological superiority of the U.S. military.

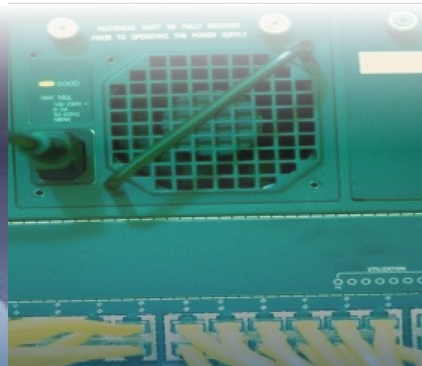
To fulfill its mission, the Agency relies on **diverse performers** to apply multi—disciplinary approaches to both advance knowledge through basic research and **create innovative technologies** that address current practical problems through applied research.

As the DoD's **primary innovation engine**, DARPA undertakes projects that are finite in duration but that create **lasting revolutionary change**.

DARPA History

SATURN F1
Rocket Engine
1960

Speech Recognition
1971



Stealth Fighter
1983

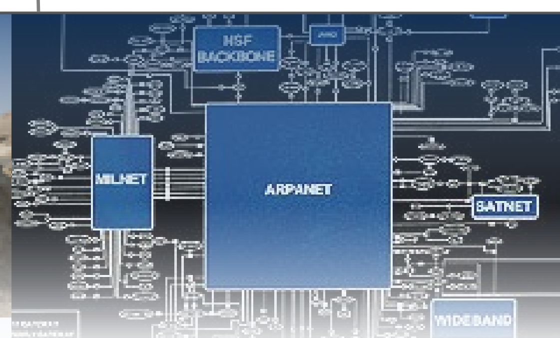
Microelectromechanical
Systems (MEMS)
1991

1960 1970 1980 1990 2000

ARPA Established
1958

M16 Assault Rifle
1965

ARPANET
1969



Global Hawk
1998

DARPA Technical Offices

BTO
Biological Technologies Office

- Neurotechnologies
- Engineering Biology
- Outpacing Infectious Disease

DSO
Defense Sciences Office

- Math, Modeling & Design
- Physical Systems
- Human-Machine Systems

I2O
Information Innovation Office

- Empower the Human within the Information Ecosystem
- Guarantee Trustworthy Computing and Information

MTO
Microsystems Technology Office

- EM Spectrum
- Tactical Information Extraction
- Globalization

STO
Strategic Technology Office

- System of Systems (SoS)
- Battle Management, Command & Control (BMC2)
- Communications and Networks
- Electronic Warfare (EW)
- Intelligence, Surveillance, and Recon
- Positioning, Navigation, & Timing (PNT)

TTO
Tactical Technology Office

- Ground, Maritime, Air, & Space Systems
- Agile Development
- Cooperative Autonomy
- Unmanned Systems
- Power and Propulsion

TTO's History

Ground Systems

M16 (Project Agile)

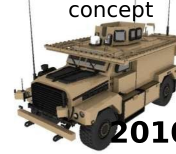
Tank Breaker

Army Tactical Missile System (Assault Breaker)

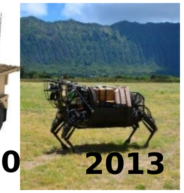
Talon

Boomerang

Netfires



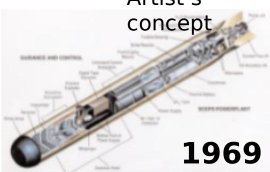
Iron Curtain



Legged Squad Support System (LS3)

Persistent Close Air Support (PCAS)

Maritime and Undersea Systems

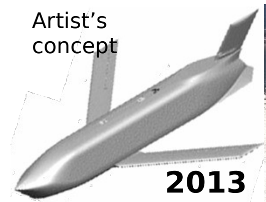


MK 50 Torpedo Propulsion System

Sea Shadow

Unmanned Undersea Vehicle (UUV)

Submarine Technology (SUBTECH)



Long Range Anti-Ship Missile (LRASM)

ASW Continuous Trail Unmanned Vessel (ACTUV)

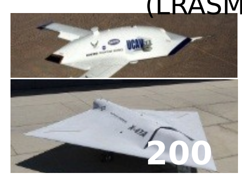
Air Systems

Have Blue

Tacit Blue

X-31

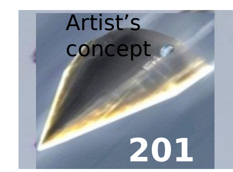
Global Hawk



X-45/46/47

A-160

Damage Tolerant Controls (DTC)

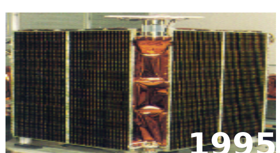


Falcon HTV-2

Space Systems

Global Low Orbiting Message Relay (GLOMR)

Pegasus



DARPASAT

Taurus

Falcon Small Launch Vehicle

MiTEX

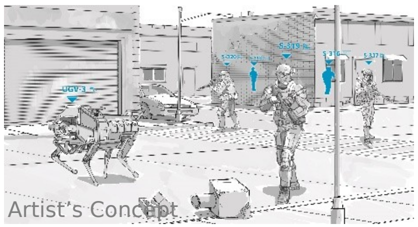
Orbital Express (OE)

Space Surveillance Telescope (SST)

Platform and System Focus Areas

Ground Systems

Deployable, mobile capable forces

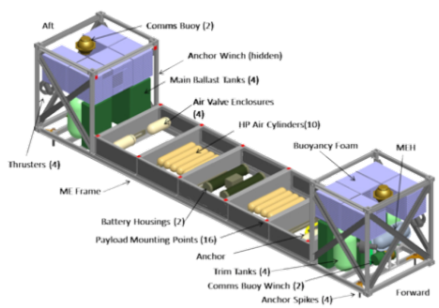


Artist's Concept

Artist's Concept

Maritime Systems

Control the sea, influence events on land

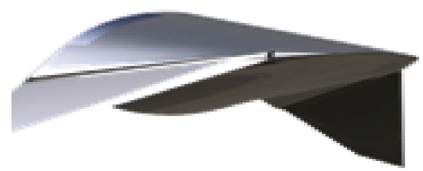


Artist's Concept

Air Systems

Extend range and minimize time

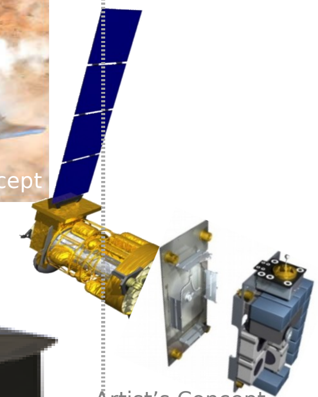
Artist's Concept



Artist's Concept

Space Systems

Resilient and flexible



Artist's Concept

Artist's Concept

Artist's concept

Cross-Cutting Themes

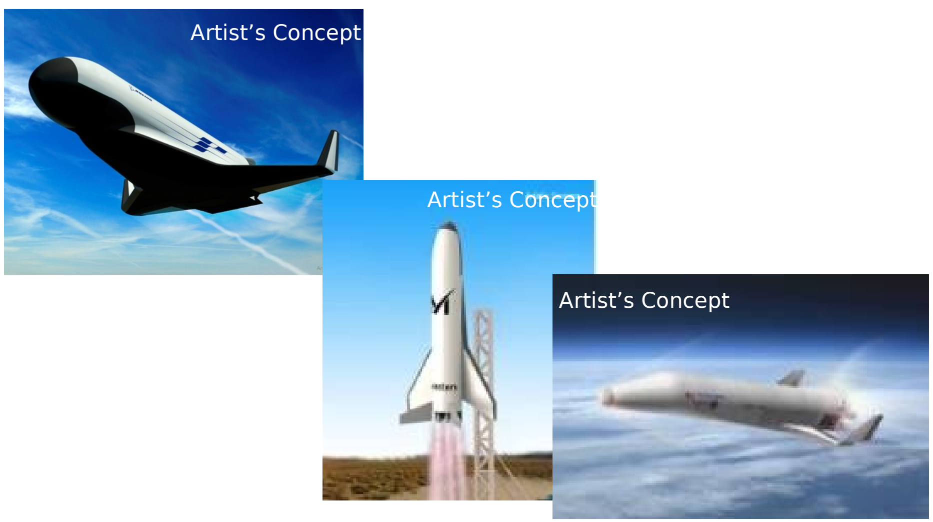
Agile development approach, cooperative autonomy, unmanned systems, power and propulsion

Resilience in Space

Goals:

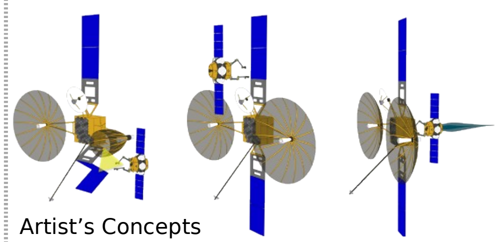
- Affordable routine access — “time to space”
- Reduce escalating systems cost
- Enhanced survivability, reconstitution and autonomy
- Real-time space domain awareness
- New capabilities

Shaping the Present

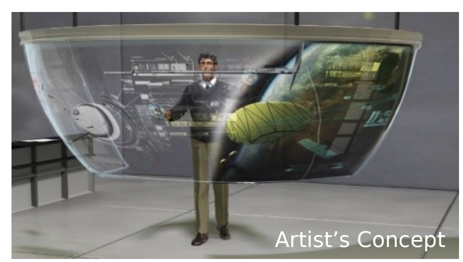


Experimental Spaceplane (XS-1)
Goal: Affordable, routine and reliable access to space

Creating the Future



Robotic Servicing of Geosynchronous Satellites (RSGS)
Goal: Enabling cooperative satellite operations

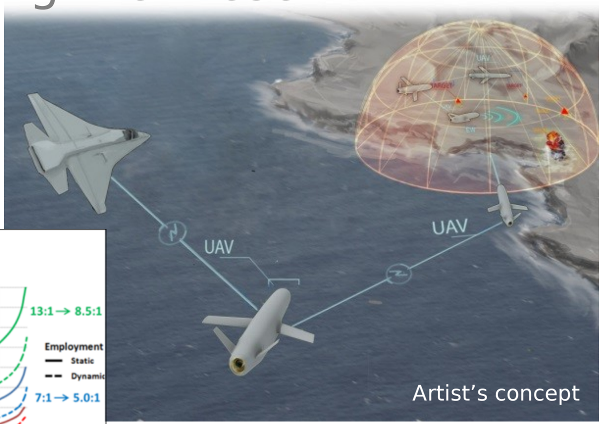


Hallmark
Goal: Real-time space domain awareness, command & control

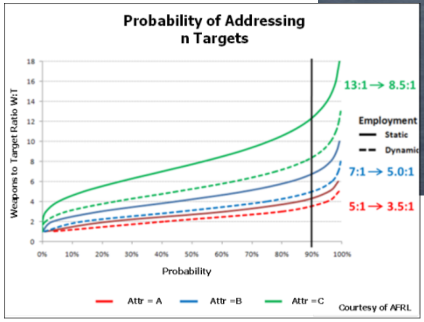
Expanding the Envelope in the Air

- Coordinated collaboration to expand capabilities to enable improved and new missions
  - High speed, collaborative precision strike and advanced munitions
- Onboard perception to support autonomy
- Increased improvements in VTOL performance capabilities
- Enabling future operational hypersonic capabilities

Shaping the Present



Artist’s concept



Collaborative Operations in Denied Environment (CODE)
Goal: Reduction in salvo size using collaborative dynamic targeting

Creating the Future


Artist’s Concept

Aircrew Labor In-Cockpit Automation System (ALIAS)
Goal: Variably reduced onboard crew for existing aircraft


rtist’s concept

Gremlins
Goal: Distributed volleys of recoverable assets

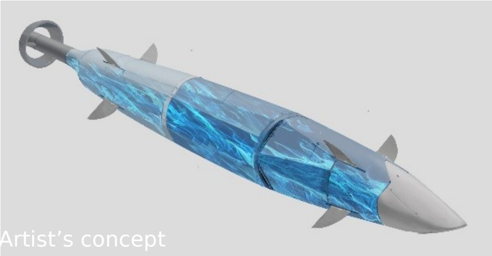
Maritime Capabilities

- Survivable and highly distributed systems to deliver effects from long distances
- Ability to perform vital missions without big platforms
- Flip measure/countermeasure cost imbalance in our favor
- Enhanced situational awareness and threat detection
- On the surface or under the sea

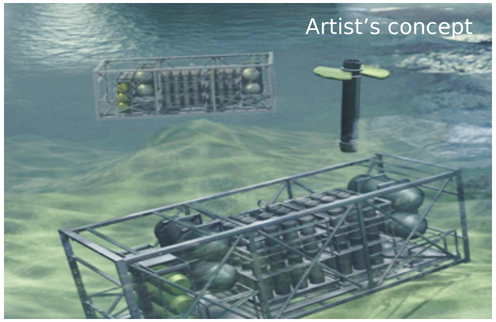
Shaping the Present

ASW Continuous Trail Unmanned Vessel (ACTUV)
Goal: Global Hawk for the high seas

Creating the Future



Blue Wolf
Goal: Underwater vehicle prototypes at speed-range combinations previously unachievable

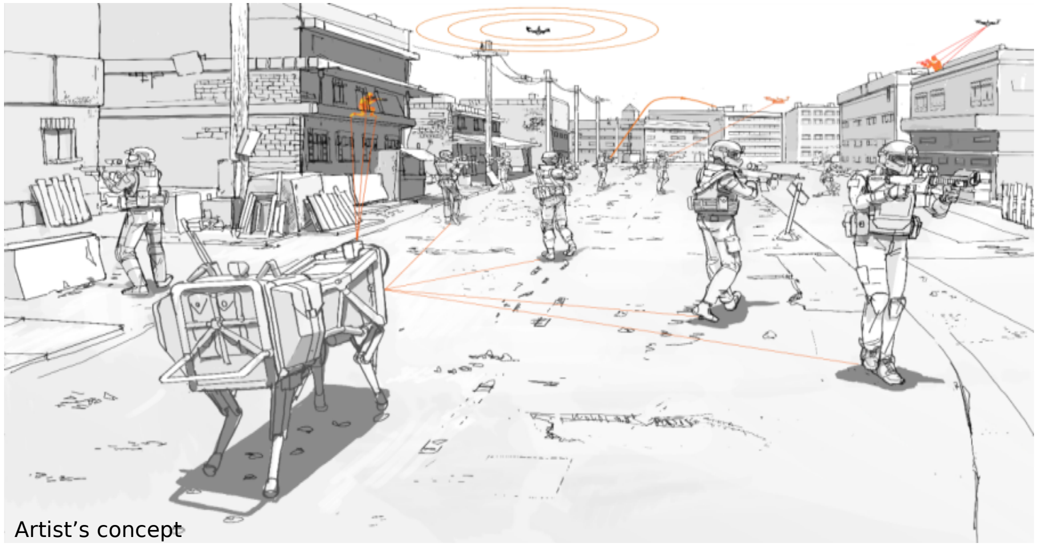


Hydra
Goal: Affordable, delivery of unmanned aerial and undersea payloads

Enabling Light, Mobile Forces

- Extend and enhance the situational awareness of small units
- Enable rifle squads to shape and dominate their battlespace (kinetic and non-kinetic)
- Modular unmanned logistics and transport to the tactical edge
- Improved detection range, accuracy and robustness
- Unit level improvements for all operations phases

Shaping the Present



Squad X
Goal: New capabilities and unit-level experimentation

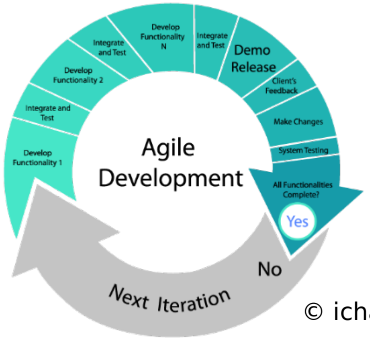
Creating the Future

Ground Experimental Vehicle Technologies (GXV-T)
Significantly improving mobility without sacrificing survivability

Aerial Reconfigurable Embedded System (ARES)
Goal: Enhance the effectiveness of small units

Enabling Capabilities to Consider

- Agile development
- Cost inversion/imposition
- Autonomous/cooperative unmanned systems
- Advanced weapons technology
- Power and propulsion



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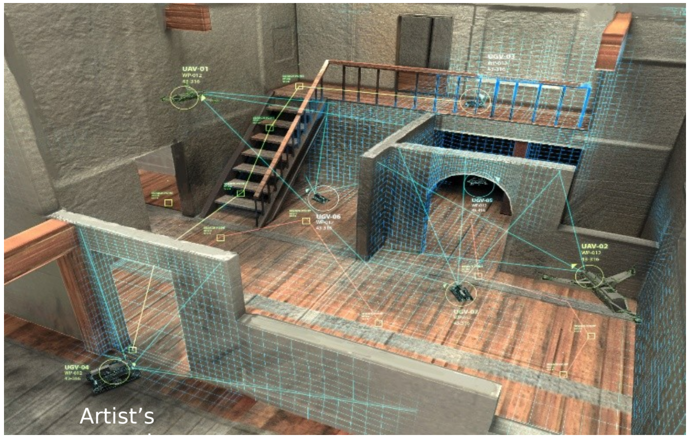

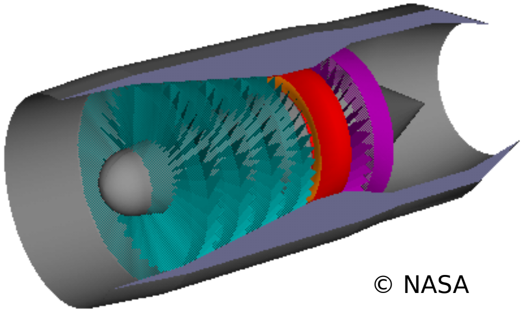

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Tactical Technology Office:
Office-Wide BAA

Ms. Pamela A. Melroy, Deputy Director
DARPA Tactical Technology Office

Briefing prepared for TTO Proposers Day

April 20-21, 2016

Why Are We Here Today?

- We want to make sure that you understand our approach, which includes:
  - The areas we are focusing on and why, so that you can be more effective in what you propose
  - Our process and the realities about the way TTO BAA-16-31 works
- We want to answer your questions:
  - During the sidebars, tell us your ideas for truly revolutionary technologies that are aligned with the program managers’ vision for their programs
  - Tell us your thoughts on how we can tap into new ideas that can strengthen our existing programs
- The interchange of ideas between DARPA and industry has always been at the heart of TTO’s approach to developing revolutionary technologies:
  - Many programs have started as seedlings from BAA submissions

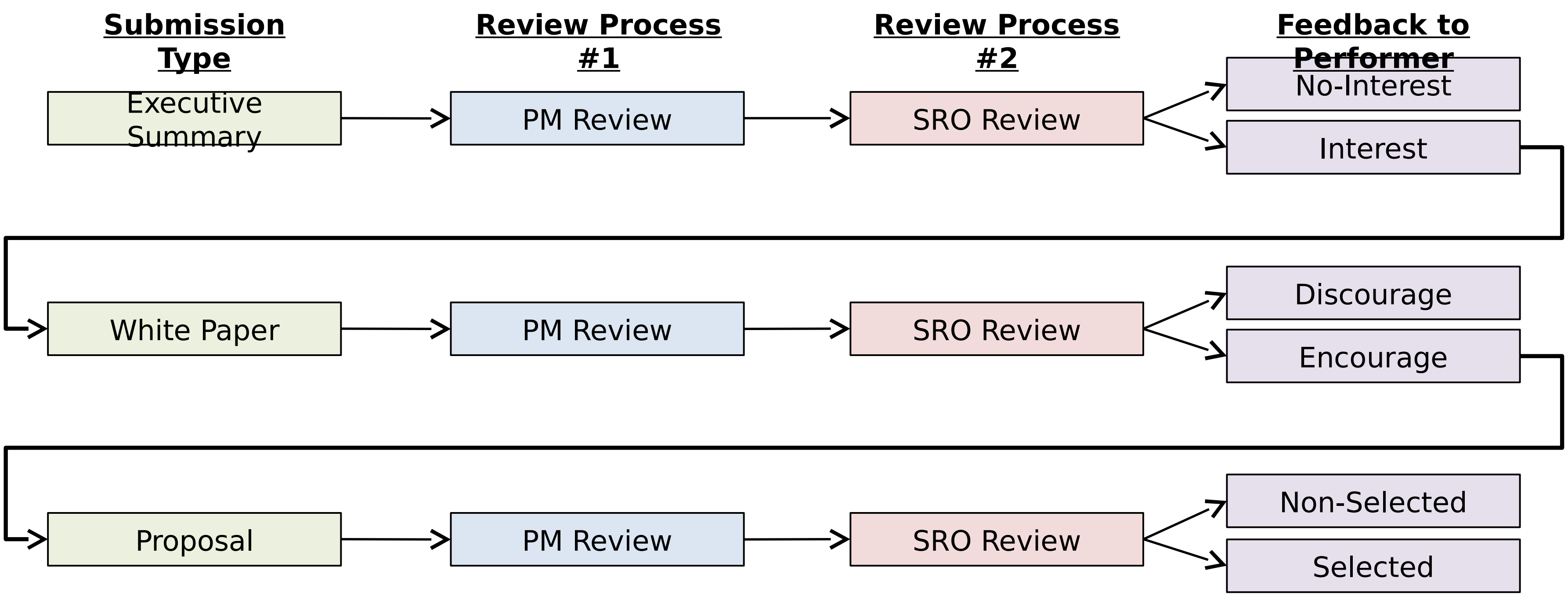
Our Engine is Made Up of Our PMs' Visions

- PMs are the ones who execute seedlings and programs:
  - Office director and deputy director can help you locate the right PM
- You may have a good idea, but if it's not aligned with someone's interest area, then it won't happen
- Feedback about your executive summaries and white papers can steer you in the right direction before submitting a proposal

How Does It Work?

- One (1) year-long BAA:
  - Designated BAA coordinator and email address
  - Does not supersede program BAAs

- Executive summaries, white papers, and proposals



How to Submit?

- DARPA's BAA website https://baa.darpa.mil
  - NEW — There is no longer a separate deadline for executive summaries, white papers, and proposals
  - Visit the website to complete the two-step registration process
  - First-time submitters will need to register for an extranet account (https://baa-registration.darpa.mil/):
    - Wait for two separate emails containing a username and temporary password
    - After accessing the Extranet, create an account for the DARPA BAA website via the "Register your Organization" link along the left side of the homepage
    - View submission instructions; all submissions must be submitted as zip files (.zip or .zipx) and be no larger than 50 MB
  - If an account has already been created it may be reused
- Proposers requesting grants or cooperative agreements may submit proposals through one of the following methods:
  - (1) Hard copy mailed directly to DARPA
  - (2) Electronic upload at http://www.grants.gov/applicants/apply-for-grants.html

Classified Submissions

- Prior to sending any classified submissions, performers must provide advance notification to the BAA coordinator via DARPA-BAA-16-31 @darpa.mil
  - Submit an unclassified cover to the website so we know the submission is coming and can track it

- Proposers choosing to submit classified executive summaries, white papers or proposals from other classified sources must first receive permission from the respective Original Classification Authority in order to use their information in replying to this BAA
  - Applicable classification guide(s) should also be submitted to ensure the proposal is protected at the appropriate classification level

- Classified submissions shall be appropriately and conspicuously marked with the proposed classification level and declassification date. Before transmitting the material, contact DARPA CDR (C/S/TS), SAPCO (SAP) or Special Security Office (SCI)
  - **Confidential and Secret Collateral Information:** Classified information at the Confidential and Secret level may be submitted via ONE of the two following methods:
    - Hand-carried by an appropriately cleared and authorized courier to the DARPA CDR
    - Mailed via appropriate U.S. Postal Service methods (e.g., USPS Registered Mail or USPS Express Mail)
  - **Top Secret materials:** Top Secret information should be hand carried by an appropriately cleared and authorized courier to the DARPA Classified Document

Things to Keep in Mind (1 of 3)

- No-Interest/Discourage means:
  - In the form you submitted, we are not interested in your idea because:
    - The submission does not present an approach to developing technology that is aligned with the DARPA/TTO focus areas and interests
    - The submission is not important to TTO's areas of responsibility as outlined in the BAA
    - The submission is not suitably structured to produce a TTO systems-level demonstration or product
    - The submission does not substantiate a revolutionary military capability within the TTO portfolio
    - The proposed approach does not clearly identify current limitations that would be overcome
    - The submission does not identify barriers to implementing new operational concepts and postulate solutions
    - The submission does not convey technology significantly beyond the state of the art
    - The submitted work does not provide sufficient information to assess the technical performance claims
  - It does NOT mean that you cannot submit a full proposal...BUT chances of success are extremely slim

Things to Keep in Mind (2 of 3)

- Common misunderstandings:
  - You can submit any time in the period, not just at the due date
  - Make sure it is relevant to TTO — your idea may be more relevant for another DARPA technical office
  - Please explain how your technology works and how it enables a new capability
  - We will not be developing your idea — you will have to do the work
    - Are you proposing a study? A demo? Tell us what you would deliver and how you would deliver it
  - Do your homework — how is the task accomplished today and how much would your technology compare in cost, performance and operations?
  - Not all this detail is needed in an Executive Summary, but you should have considered all of it when submitting
  - We are looking for revolutionary new capabilities, not technology that needs funding to be fielded

Things to Keep in Mind (3 of 3)

- Interest/Encourage means:
  - We find your idea interesting and we would like to know more
  - It does NOT mean that you are funded or that a full proposal will be accepted

- Funding and seedling length expectation:
  - Intent is to fund seedlings at < $1M
  - Typically, seedlings are 12-18 months in duration unless there is valid justification for a longer effort
  - Efforts larger than seedlings are likely to be handled as a program — options or through a program BAA
  - Okay to propose options for a larger follow-on program
    - You may submit a cost proposal with various options (1, 2…n) so that you have a phased approach, but this would only be one volume

Do and Don'ts

- DO read the TTO BAA-16-31 document in its entirety
- DO use the executive summary and white paper process
- DO forward any questions related to the DARPA/TTO BAA-16-31 to DARPA-BAA-16-31@darpa.mil

- Do NOT recirculate proposals rejected from program BAAs
- Do NOT hand-carry paper copies to the DARPA building
- Do NOT email/fax in your executive summary, white paper, or proposal to the TTO BAA-16-31 mailbox
- Do NOT call to check on the status of your submission

Questions?

- Is the feedback in the letters useful?

- How can we improve the process?*

*...please don't ask us to change the Federal Acquisition Regulations!

DARPA-BAA-16-31
Innovative Systems for Military Missions
Tactical Technology Office (TTO)

Mr. Peter Donaghue, Contracting Officer
DARPA Contracts Management Office

Briefing prepared for TTO Proposers Day

April 20-21, 2016

DARPA-BAA-16-31

- FedBizOpps — www.fbo.gov
  - BAA
  - Amendments
  - Industry day slides

- Due dates for Executive Summaries, White Papers, and Proposals

- Any discrepancy between what is presented today and the BAA, the BAA takes precedence

BAA Process: FAR Part 35

- Described in FAR Part 35 “R&D Contracting”

- 35.016(a) The BAA technique shall only be used when meaningful proposals with varying technical/scientific approaches can be reasonably anticipated

BAA Process: Evaluation and Award

- FAR 35.016(d) — "Proposals received as a result of the BAA shall be evaluated in accordance with evaluation criteria specified therein through a peer or scientific review process. Written evaluation reports on individual proposals will be necessary but proposals need not be evaluated against each other since they are not submitted in accordance with a common work statement."

- Proposals are not ranked. No color, adjectival, or numerical "scoring" systems are employed during the Scientific/Technical Review Process.

- Proposers are attempting to demonstrate that their proposed research meets the agency's requirements

- Distinct from RFP/RFQ-based procurement when the evaluation and selection process is premised on making meaningful comparisons between and among competing proposals submitted in response to a common set of requirements

Evaluation Criteria:

1. Overall Scientific and Technical Merit
2. **Potential Contribution and Relevance to the DARPA/TTO Mission**
3. Cost Realism
4. Realism of Proposed Schedule
5. Proposer’s Capabilities and/or Related Experience

35.016(e) The primary basis for selecting proposals for acceptance shall be technical, importance to agency programs, and fund availability; Cost realism and reasonableness shall also be considered to the extent appropriate

Not a price competition; cost realism is assessed

- Cost realism is evaluated to assess the extent to which proposed costs are realistic for the technical and management approaches proposed

BAA Process: Award Information

- Multiple Awards anticipated
  - Generally < $1M and 18 months, but options may be proposed that lead to a larger effort

- DARPA reserves the rights to:
  - Select for negotiation all, some, one, or none of the proposals received and to make awards with/without discussions
  - Award all, some, one or none of any options proposed
  - Accept proposals in their entirety or only portions of proposals for award
    - Segregate portions of proposal into pre-priced options
    - Negotiations may be opened with proposer
  - Fund proposals in phases with options for continued work at the end of one or more of the phases
  - Remove proposers from award consideration should the parties fail to reach agreement on award terms, conditions and cost/price

BAA Process: Award Instruments

- Procurement (FAR based) contract, other transaction agreement, cooperative agreement, or grant
  - Cost Reimbursement Contracts: Proposers without an accounting system considered adequate by DCAA should submit an SF 1408
  - Other Transaction Agreement — must meet eligibility criteria:
    - Non-traditional defense contractor “participating to a significant extent”;
    - All significant participants are small businesses/non-traditionals; or
    - If none of the above, must provide minimum 1/3 cost share

- Fundamental Research
  - Indicate in proposal whether scope of research is fundamental or not
  - Non-fundamental: Pre-publication approval will be required
    - Public Release and Dissemination of Information clause
    - Must submit a request for public release to Public Release Center (PRC)

DARPA CO has sole discretion to select award instrument type and to negotiate all instrument terms and conditions with selectees

BAA Process: Communications

- ALL BAA questions to DARPA-BAA-16-31@darpa.mil

- After Receipt of Proposals — GOVT PCO may communicate with proposers to clarify some aspect of the proposal that is not clear

- Only a Contracting Officer may obligate the Government

- After selections, informal feedback may be provided upon request

BAA Process: Eligibility Information

- All responsible sources capable of satisfying the Government's needs may submit a proposal that shall be considered by DARPA

- Non-U.S. organizations and/or individuals
  - May participate to the extent that such participants comply with any necessary nondisclosure agreements, security regulations, export control laws, and other governing statutes applicable under the circumstances

- Government agencies/labs, FFRDC's: subject to limitations
  - Government agencies/labs, FFRDCs cannot propose to this BAA in any capacity, **UNLESS** they can clearly demonstrate the work is not otherwise available from the private sector AND they also provide written documentation citing the specific statutory authority (as well as, where relevant, contractual authority) establishing their eligibility to propose to government solicitations

- Organizational Conflicts of Interest
  - Without prior approval or a waiver from the DARPA Deputy Director, in accordance with FAR 9.503, a contractor cannot simultaneously provide scientific, engineering, technical assistance (SETA) or similar support and also be a technical performer
  - Must address in your proposal if providing SETA or similar support to any DARPA technical office(s) through an active contract or subcontract

BAA Process: Proposal Requirements

Executive Summaries, White Papers, and Proposals

- Submit through DARPA's BAA Website: https://baa.darpa.mil
  - 2 step registration process
  - No fax or emails submissions
  - Proposal must be submitted as Zip file

Grants/Cooperative Agreements

- Proposers requesting grants or cooperative agreements may submit proposals through one of the following methods:
  - Hard copy mailed directly to DARPA; or
  - Electronic upload per the instructions at http://www.grants.gov/applicants/apply-for-grants.html
    - Grants.gov registration checklist: http://www.grants.gov/documents/19/18243/OrganizationRegChecklist.pdf

BAA Process: Proposal Requirements

- **<u>Read the BAA and Follow the Proposal Instructions</u>**
  - Assists Government reviewers in clearly understanding what is being proposed
  - Supports a timely negotiation and award
- Volume I, Technical and Management Proposal
  - Summary of Proposal
  - Detailed Proposal Information
    - Non-proprietary SOW, Technical Rationale, Risk, etc.
- Volume II, Cost Proposal
  - Cost tables in MS Excel format w/ formulas intact are strongly encouraged
  - Cost breakdown (Base & Options): Direct labor, indirect rates, ODC, Material
  - Subcontractor proposals — Unsanitized (may be submitted to Govt directly)
  - Supporting documentation for proposed ODC & Material amounts
- Large businesses: Subcontracting Plan required IAW FAR 19.702(a)(1) for all FAR contracts > $650K

BAA Process: Administrative & National Policy Requirements

- Human Subjects Research
- Animal Use
- Export Control — Clause/Language will be included in award
- Subcontracting
- System for Award Management (SAM)
- Cost Accounting Standards (CAS) Notice & Cert
- Executive Compensation for Contracts and 1st Tier subs: all awards >$25K
- Safeguarding of Covered Defense Information and Cyber Incident Reporting
- Online Representations & Certifications — FAR & DFAR
- Wide Area Workflow (WAWF)
- i-Edison

BAA Process: Intellectual Property

Data Rights Assertions — DFARS 252.227-7013/7014

- Identify all non-commercial and commercial technical data & computer software to be generated, developed, and/or delivered to which the Government will receive less than Unlimited Rights and assert specific restrictions on those deliverables
- Assertions required for both Prime and Subs
- Use format required in BAA (DFAR 252.227—7017)
  - Use defined “Basis of Assertion” and “Asserted Rights Category”
  - Justify “Basis of Assertion” with summary of intended use
  - Avoid broad/vague assertions
- Data rights assertions will be evaluated and will be incorporated into any contract award as an attachment
  - Potential Contribution and Relevance to the DARPA/TTO Mission
- Patents: Include documentation proving your ownership/possession of appropriate licensing rights to all patented inventions

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TTO Proposers Day 2016

Dr. Ashish Bagai, TTO Program Manager

Briefing prepared for TTO Office-Wide BAA Proposers Day

April 20-21, 2016

VTOL X-Plane

Artist's concept

Purpose:

- Design, develop, and demonstrate improvements in VTOL performance capabilities:
  - High speed flight
  - Improved hover
  - Improved cruise
  - Uncompromised useful load
- Flight test a technology demonstrator aircraft to demonstrate all program performance objectives
- Potential transition partners: AFSOC, ARSOAC, AMRDEC, AATD, AFDD, ONR, NAVAIR, NASA, OSD AT&L

Key Technologies:

- Novel VTOL configurations
  - Distributed electric propulsion
  - Tilt wing/canard
- Innovative sub-systems
  - Hybrid-electric power generation
  - Variable-duct geometry
- Creative integration of configurations and subsystems to:
  - Expand limit boundaries
  - Improve power loading
  - Increase lift-to-drag ratio
  - Reduce weight-empty fraction

Metrics:

- Sustained max. speed: ≥ 300 kt
  - SOA: 150-170 kt
- Hover efficiency (aircraft FM): ≥ 75%
  - SOA: 60 percent
- Cruise efficiency (aircraft L/D): ≥ 10
  - SOA: 4-5
- Useful load: ≥ 40% GW
  - SOA: 35-40 percent

Repudiate Existing Comfort Zones

Other DoD VTOL efforts — FVL, JMR Technology Demonstrator

- Advise DoD on technologies to address upcoming requirements
- Enhancements to proven configurations enabled by new technologies
- “Prototype” for future DoD vertical lift aircraft
- Clearly defined mission space

Sikorsky-Boeing SB-1

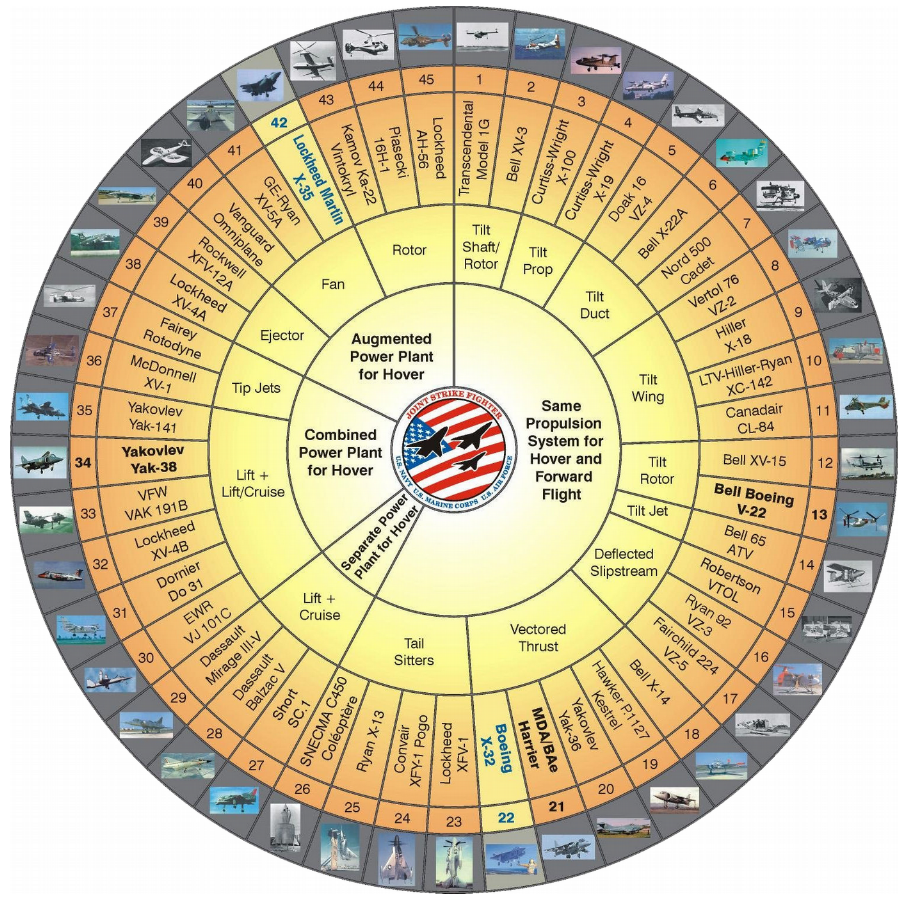
Bell V-280 Valor

Karem TR36TD

AVX

E-Volo Volocopter

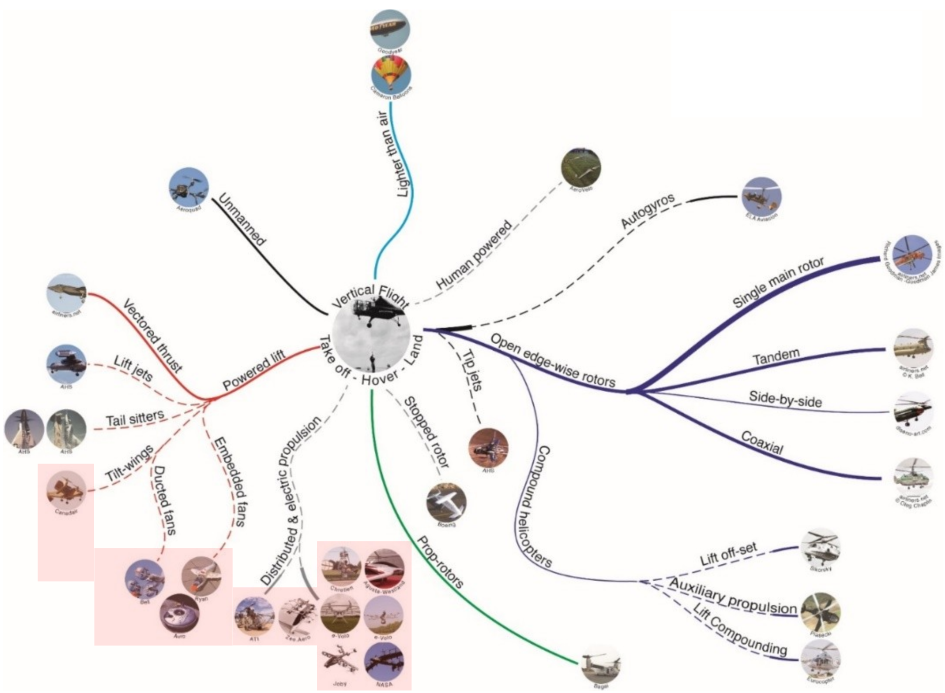
NASA GL-10



Enable New Trade Spaces

VTOL X-Plane Program

- Defined by the program objectives
- Unconstrained by conventional paradigms
- Redefines design approach for future VTOL air vehicles
- Radically new and innovative designs, technologies, capabilities
  - Integrated, distributed propulsion
  - Over actuated control systems
  - Hybrid-electric design
  - Enables transmission agnostic configurations



Aurora Flight Sciences *LightningStrike*

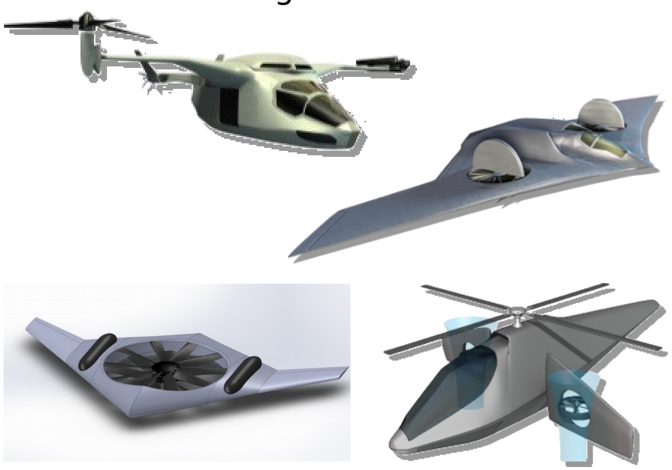
Boeing *Phantom Swift*

Artist's concept

Technical Areas of Interest

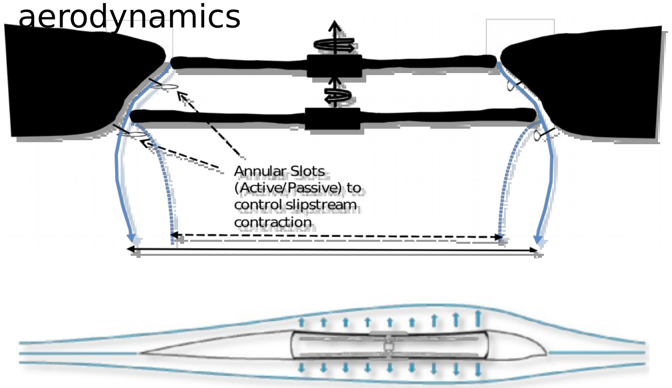
- Creating remarkable and disruptive new applications and capabilities
- Platforms, subsystems, integrated solutions
- High-impact solutions and design spaces

Innovative configurations

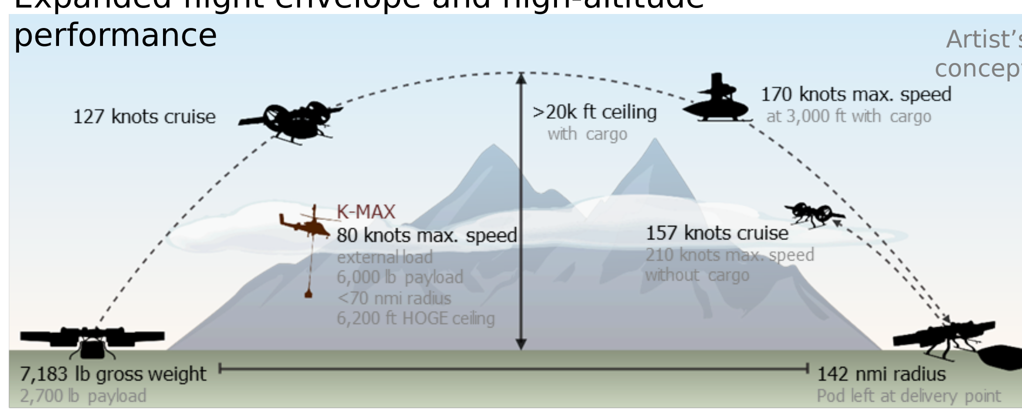


Expanded operational capabilities

Fundamental aerodynamics



Expanded flight envelope and high-altitude performance



Subscale Demonstrator First-Flight

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Dr. Peter Erbland, TTO Program Manager

Briefing prepared for TTO Office-Wide BAA Proposers Day

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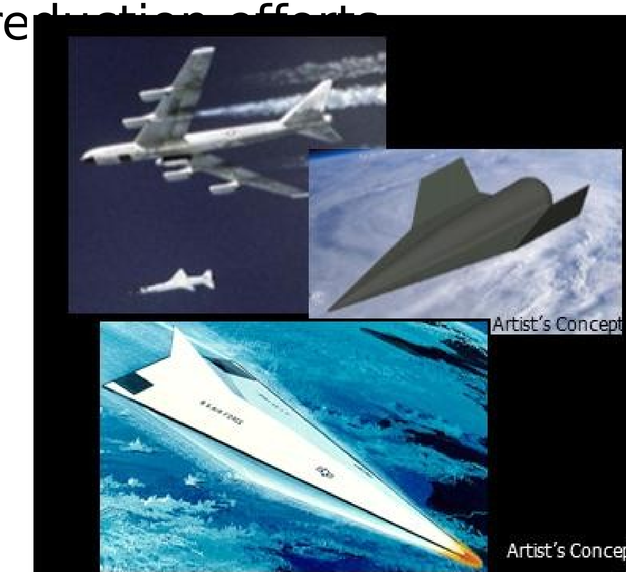
Tactical Boost Glide (TBG)

Purpose:	Key Technologies:	Metrics:
• The Tactical Boost Glide (TBG) program is a joint DARPA/Air Force effort that seeks to develop and demonstrate technologies to enable air-launched, tactical-range hypersonic boost glide systems	• Configurations with aerodynamic and aerothermal performance, controllability and robustness for a wide operational envelope • System attributes and subsystems required to be effective in relevant operational environments • Approaches to reducing cost and improving affordability for demonstration system and future operational systems • Ground and flight testing to mature critical technologies and demonstrate system performance • Transition partner: U.S. Air Force	• Total Range (nmi) • Time of Flight (min) • Payload (lbs.) • Accuracy (Circular Error Probability, ft) • Impact Velocity (fps) • Cost ($)

Tactical Boost Glide Progress

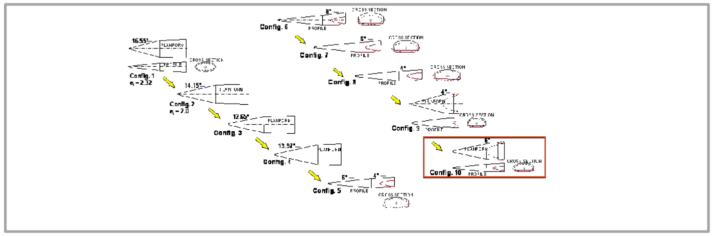
- Completed trade studies and conceptual designs of objective operational systems
- Derived demonstration system designs and critical technologies from the objective systems
- Completed demonstration system preliminary designs
- Initiated technology development and risk-reduction efforts
- Developed flight test concepts and plans



Interest Areas

Advanced Aero-Configurations

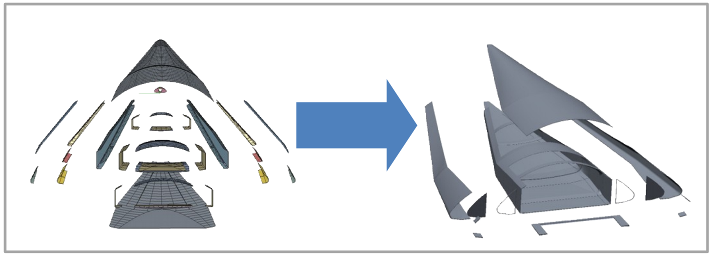
- Next generation aero-configurations
- Benefits — high L/D performance, robust aerodynamic control and energy management capabilities



High L/D with robust 3-axis control

Hot Structures for Hypersonic Vehicles

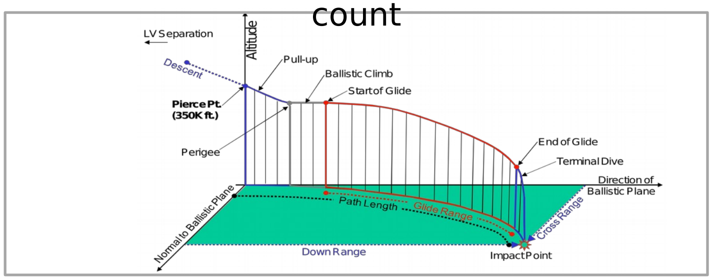
- Demonstrate material maturity, optimal structural design and affordable manufacturing approaches for hypersonic systems
- Benefits — robust design with higher margins and reduced time/cost to manufacture



Stable properties, Reduced part count

Guidance, Navigation, and Control (GNC)

- Robust adaptive guidance and control
- Real-time, highly constrained multi-phase optimal trajectory generation
- Benefits — expanded flight envelope, increased control, ability to optimize system and mission performance during flight, reduced mission planning times

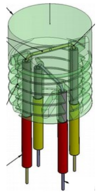


Real-time adaptation and optimization

Advanced Instrumentation

- Instrumentation approaches to address critical deficiencies, especially aeroshell thermal and recession, and vehicle “air data” measurements
- Benefits — enable collection of critical data for aeroshell thermal performance assessment and for adaptive GNC and trajectory optimization capability

Flush Air Data Port
Courtesy HTG Goettingen



C/C Thermocouple Plug

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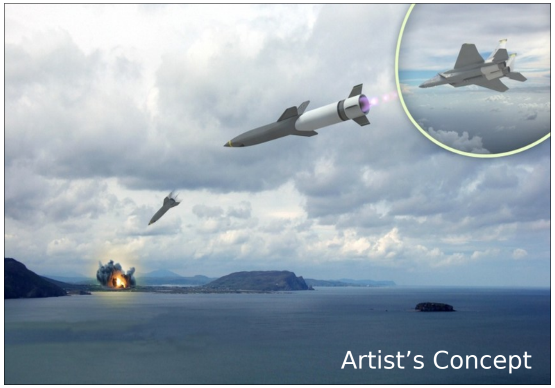
Mr. Mark Gustafson, TTO Program Manager

Briefing prepared for TTO Office-Wide BAA Proposers Day

April 20-21, 2016

Hypersonic Air-breathing Weapon Concept (HAWC)

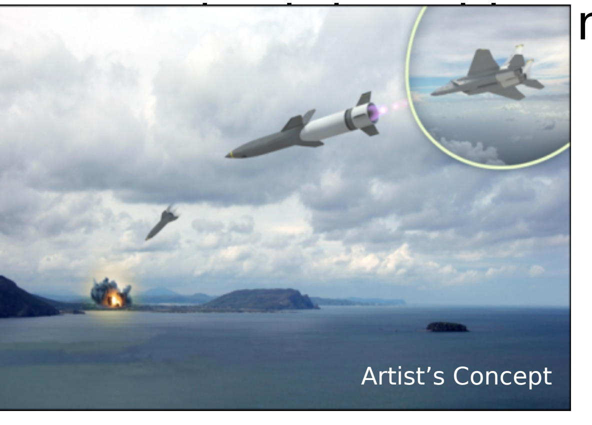


Purpose:	Key Technologies:	Metrics:

• The Hypersonic Air-breathing Weapon Concept (HAWC) program aims to develop and demonstrate technologies that would enable transformational changes in responsive, long-range strike capabilities against time-critical or heavily defended targets
 	
• Joint DARPA/Air Force (AFRL) program
	• Three critical technology challenge areas or program pillars — air vehicle feasibility, effectiveness and affordability:
	
	  • Advanced air vehicle configurations capable of efficient hypersonic flight
	
	  • Hydrocarbon scramjet propulsion to enable sustained hypersonic cruise
	
	  • Thermal management approaches designed for high-temperature cruise
	
	  • Affordable system designs and manufacturing
		• HAWC intends to build on the advances made by the previously funded X-51 program in terms of improving capabilities for speed, range and altitude

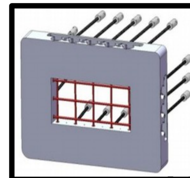
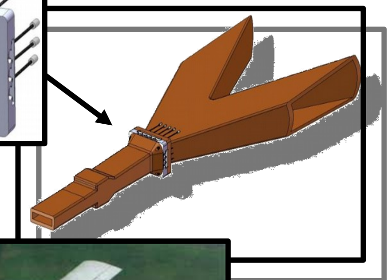
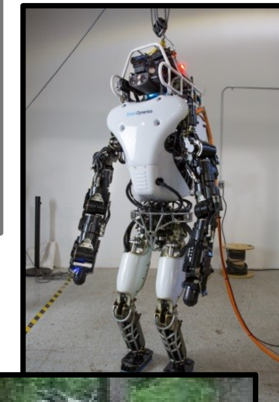
HAWC Progress

- Completed objective system trade studies and conceptual design definition
- Derived hypersonic air-breathing missile demonstration system design from the objective system
- Conducted preliminary design of HAWC missile demonstration system
- Conducting risk reduction testing of enabling subsystem technologies
- Developing flight testing plans for the h missile demonstrator

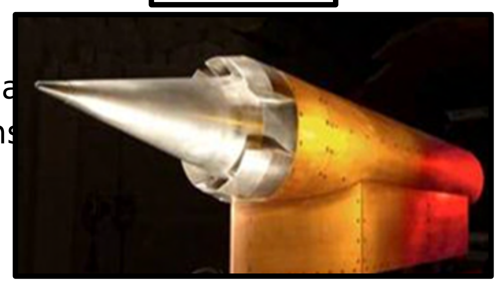
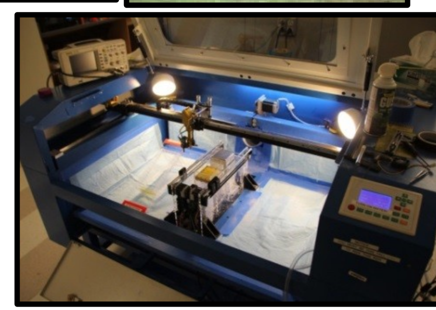


Interest Areas and Future Vision

- Innovative Missile Propulsion Concepts
  - Rotating detonation engine or turbine integrated with dual-mode ramjet
- Non-Intrusive Diagnostics
  - Sensors for high-temperature applications
  - Internal flow diagnostics
  - Air-data systems
- Innovative Internal Combustion Engine Concepts
  - Compact
  - Specific power > 2hp/lb
  - Specific fuel consumption of < 0.30 pph/hp
  - Unmanned Aerial Vehicles and robotics applications
- Additive Manufacturing Demonstrations
  - Lightweight superalloys or composite materia
  - Ram/Scramjet powered vehicle configurations



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Mr. Jean-Charles Ledé, TTO Program Manager

Briefing prepared for TTO Office-Wide BAA Proposers Day

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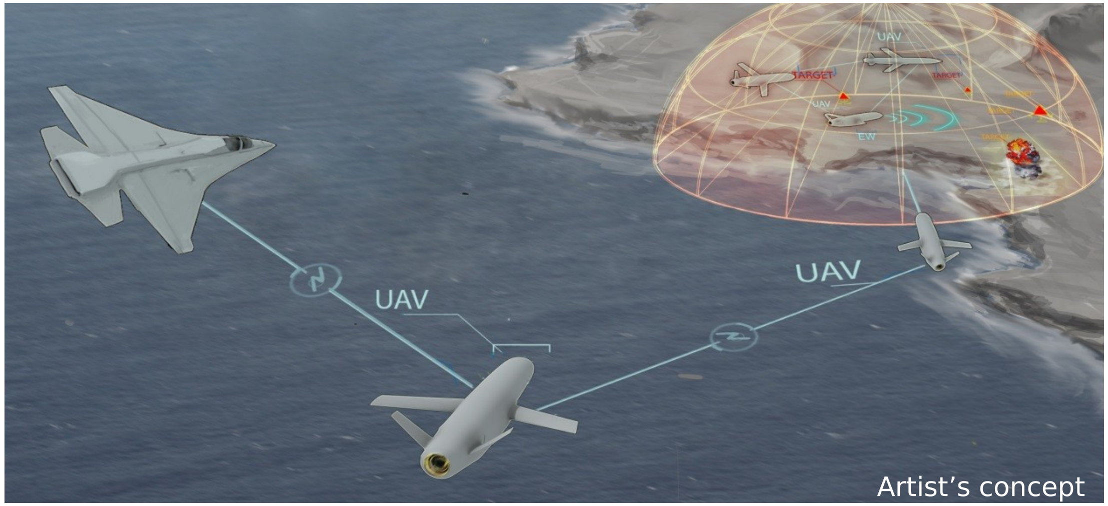
Collaborative Operations in Denied Environment (CODE)



Artist's concept

Purpose

- Develop and demonstrate algorithms that will expand the mission capabilities of unmanned aircraft through autonomy and collaborative behaviors
- Enable collaboration in difficult communication environment
- Provide interface to mission commanders and mission planners
- Develop software architecture compatible with emerging open standards and retrofittable into existing platforms

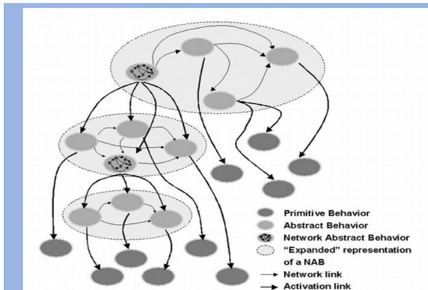
Key Technologies

- Vehicle level autonomy:
  - Complex flight path generation
  - Onboard sensor exploitation
- Collaborative autonomy:
  - Intermittent, low bandwidth comms
  - Highly autonomous dynamic reactions
- Supervisory Interface:
  - Change from operator to supervisor
  - Break linear operator-platform scaling
- Develop S/W in open architecture compatible with emerging standards
- Demo full mission capability in phased flight demonstrations on GFE platforms
- Transition: Current and future unmanned aircraft for Navy, Air Force, Army, Marine Corps

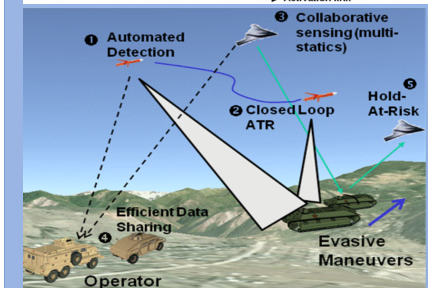
Metrics

Mission efficiency	> Two-fold performance improvement over reference
Communication requirements	≤ 50 kbps to and from Command Station
Manning	≤ 1 supervisor
Command station	Compatible with tactical deployment
Openness of the architecture	High rating per OAAT*
Transition-ability	Upgrade cost less than 10 percent of reference cost
Multi-mission capability	> 90 percent commonality between 3 reference missions

CODE Status

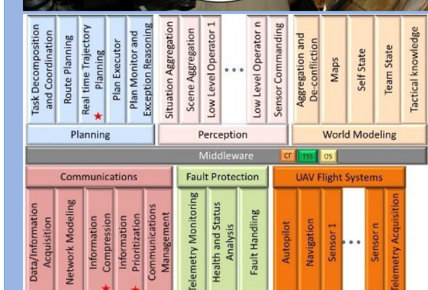


Collaborative Autonomy

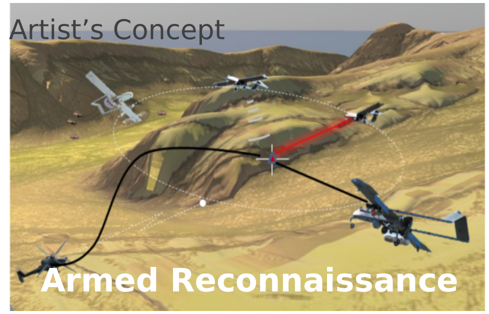


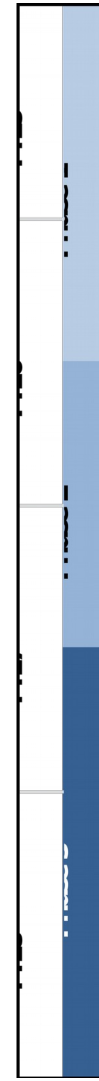
Vehicle-Level Autonomy

Supervisory Interface



Open Architecture for Distributed System





Concept Validation through simulation — Operational system design — Critical technology development

Initial s/w development limited flight test with 1 or 2 a/c

End-to-end flight demo using 6 live +n virtual assets emulating GPS and comms denied

Planned Schedule

Interest Areas and Future Vision

- Autonomy for Aerial Vehicles
  - Improved perception — decoy defeat
  - Collaboration among heterogeneous vehicles
- Advanced flight controls
  - Fault-tolerant/adaptive
  - Multi vehicles in close formation or connected
- Advanced vehicle configurations or critical airplane subsystems that improve mission performance by an order of magnitude
- Counter-UAS
  - Detect, identify, neutralize
- Counter-raid
  - Low-cost, robust neutralization mechanisms
- Precision strike in urban terrain
  - 3-D targeting
  - Highly maneuverable munitions
- Any ideas to reduce the time to deploy new DoD capabilities by ~2 orders of magnitude

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Dr. Daniel Patt, TTO Program Manager

Briefing prepared for TTO Office-Wide BAA Proposers Day

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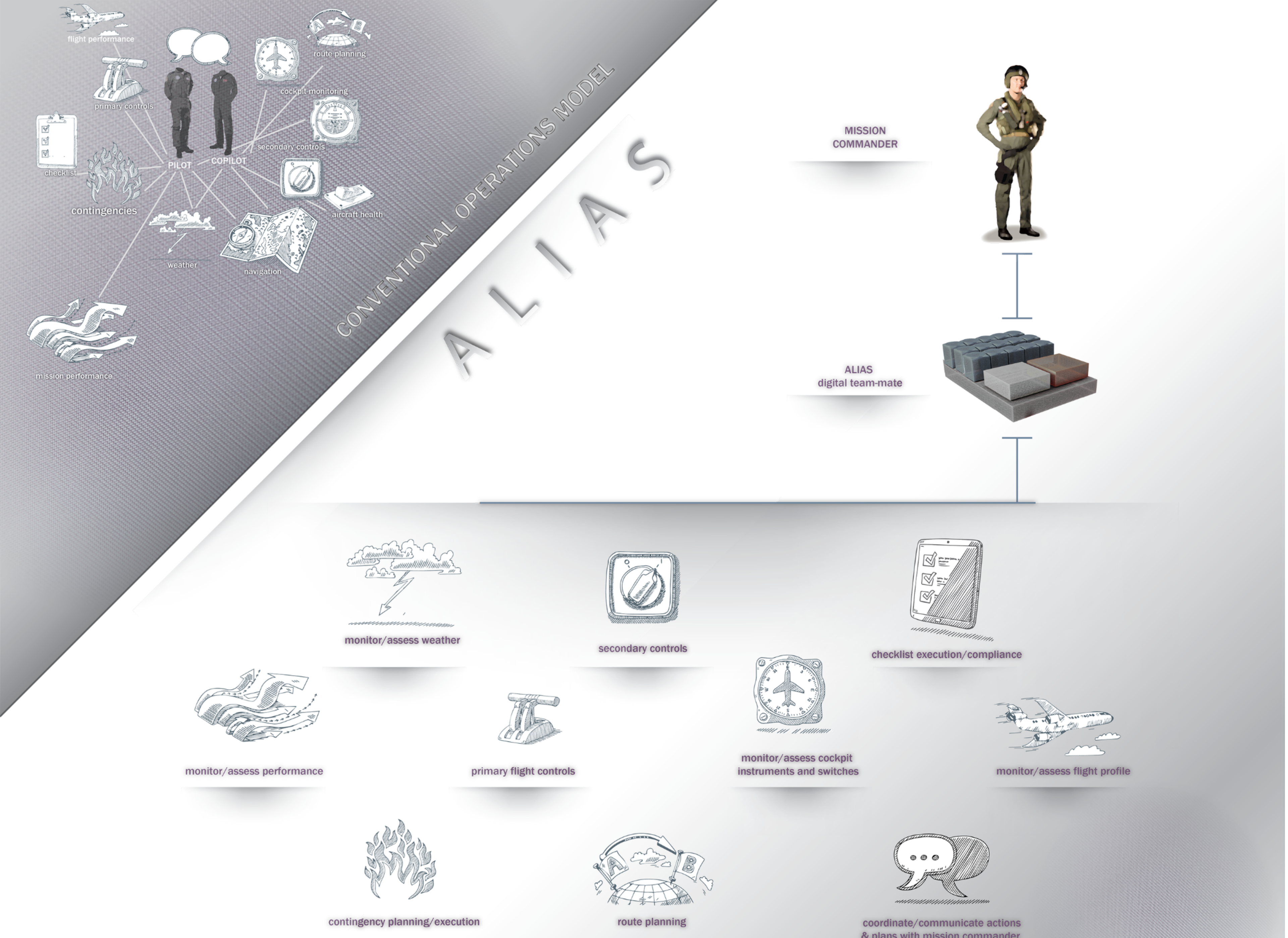
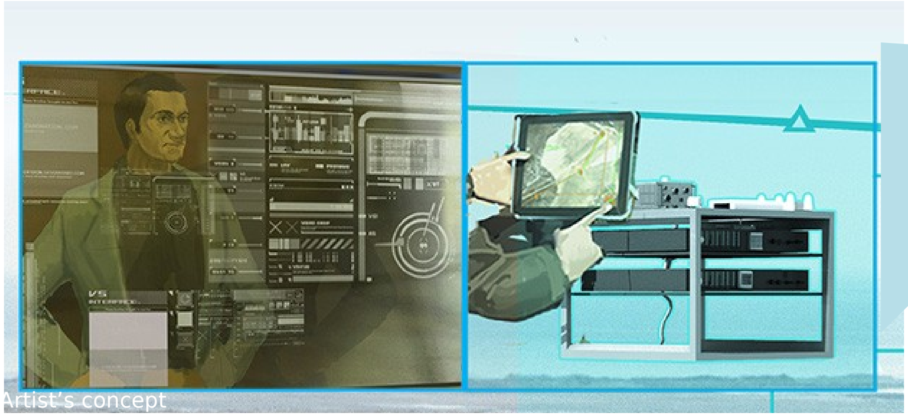
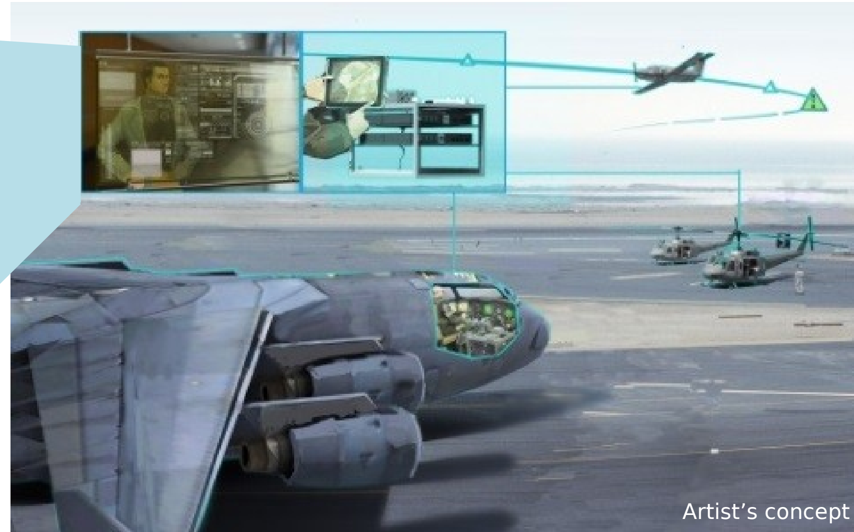


Artist's concept

Aircrew Labor In-Cockpit Automation System (ALIAS)



Artist's concept


Artist's concept

Demonstrate a flexible, extensible automation toolkit for existing aircraft that enables safe reduced crew operations

Purpose:	Key Technologies:	Metrics:
• Demonstrate a tailorable, drop-in kit that enables the addition of high levels of automation into existing aircraft • Enable management of all flight activities, including failure of aircraft systems, and permit an operator to act as a mission commander with the ability to intervene, allowing the operator to focus on higher-level mission objectives	• Minimally invasive interfaces to existing aircraft • Rapid and verifiably complete knowledge acquisition and codification • Human interface: Human operator provides high-level input and mission-level supervision and is not engaged in lower-level flight maintenance tasks that demand constant vigilance	• Rapid adaptation of ALIAS capabilities to new aircraft types • Rapid installation of ALIAS into host aircraft • ALIAS capable of takeoff-to-landing operability of aircraft • Diagnose and respond to failures via procedure • Accept mission apps for extensibility • Minimal impact to airworthiness

ALIAS Challenges and Progress

- Spiral development model
- Rapid early program progress
- Year 1 flight demonstrations of key technologies

FY15	FY16	FY17	FY18

Phase I
Concept Design

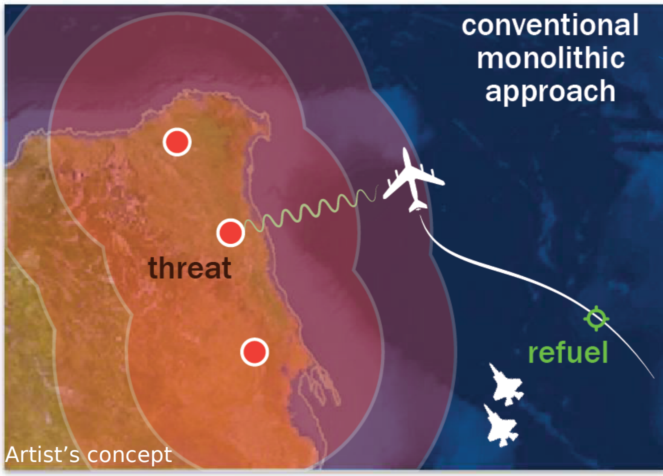
Phase II
Proof of Concept

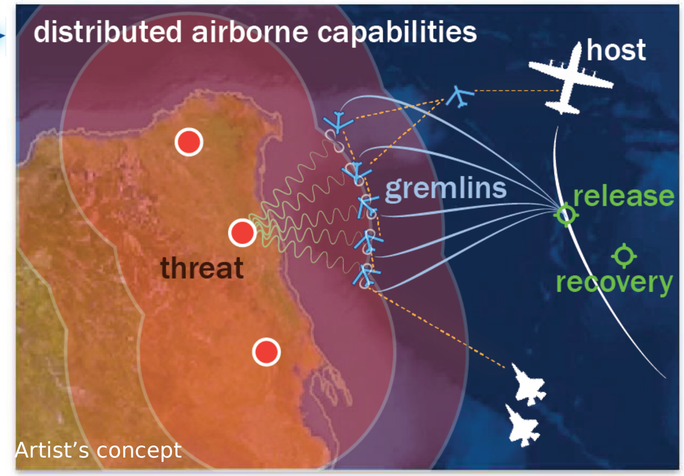
Phase III
System Refinement and Validation

Gremlins Vision

Platform enabler for a new class of distributed airborne capabilities

Move away from approach reliant on effectiveness/ survivability of individual, monolithic platforms





In distributed model, a volley of small vehicles would be air-launched, execute distributed warfare missions, and could be recovered

but: must solve small platform range problem

Provide cost-effective contested/denied environment capability

- Host-symbiont concept would overcome range and responsiveness limitations inherent in small platforms
- Recovery capability would facilitate reuse of costly payloads (reduce cost per use)
- Quantity scalable to saturate adversary defensive systems

Enabler: Air-launched, air-recoverable platforms – gremlins

- Standoff employment, loiter to support role
- Scale to one-way employment for high-intensity conflict
- Smallest possible vehicle size (reduce flyaway cost, increase quantity carried)
- Volley deploy and recover with existing host aircraft

Gremlins

Artist's Concept

Artist's Concept

Purpose:	Key Technologies:	Metrics:

• Proof-of-concept of air-launched, recoverable, volley-quantity unmanned systems
• Platform enabler for a new class of distributed airborne capabilities
• Provides cost-effective multi-environment capability
• Enables scalable, responsive power projection for distributed architectures
	• Integration of recovery system with aircraft
	• Turbulence rejection
	• Low-cost, attritable airframe
	• Small, distributed payloads
	• Precision station keeping
	• Low-force, high-reliability mating
	• Turbulent-zone transit
		• Objective system:
		  • 300+ nmi radius
		  • 1.0+ hr loiter
		  • Rapid gremlin recovery quantity
		• Demonstration system:
		  • Scale relevant to objective vision
		  • Flight demo to measure parameters corresponding to objective

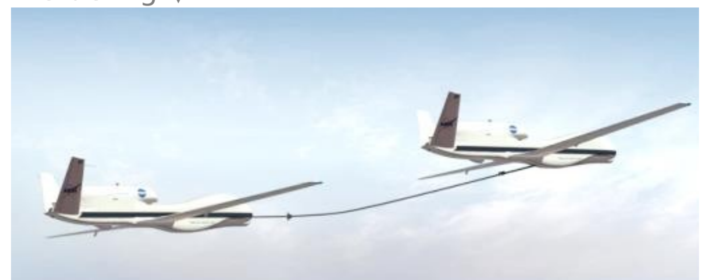
Gremlins Challenges and Progress

Historic View

Historic use of air-launched, manually air-recovered drones for ISR ▼

New Developments

DARPA development of automated aerial refueling ▼



	FY2016	FY2017	FY2018	FY2019	FY2020
Planned Schedule	Phase I: Conceptualization	Phase II: Design and Risk Reduction	se III: Flight Validation		

Interest Areas

- Novel systems architectures that are designed to enable fundamentally different ways of approaching problems, with high potential for game-changing impact

- Technology elements
  - Robotics
  - Human interfaces
  - Collaboration toolsets
  - System control
  - Verification
  - Manufacturing
  - Adaptive systems
  - Perception systems
  - Fault tolerance
  - Air, maritime, ground domains

Teaming constructs

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TTO Proposers Day 2016

Mr. Christopher Clay, TTO Program Manager

Briefing prepared for TTO Office-Wide BAA Proposers Day

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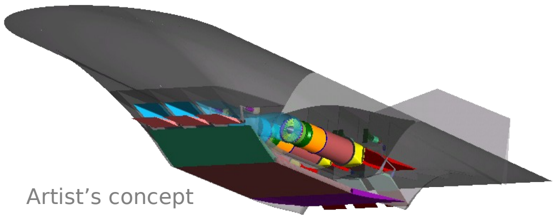
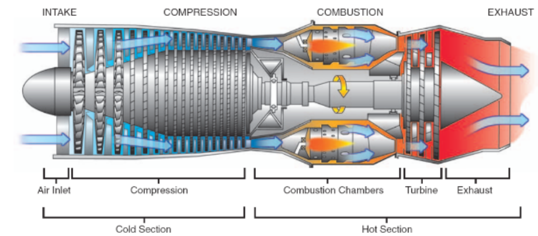
Potential Program: Advanced Full-Range Engine (AFRE)

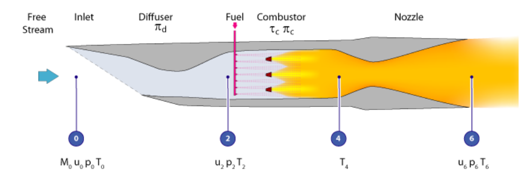


Artist's concept

Goal: Ground demo of turbine-based combined cycle (TBCC) technology



Dual Mode Ramjet (DMRJ)



Artist's concept

Purpose:

- Develop and demonstrate turbine-based combined cycle (TBCC) propulsion technology to enable hypersonic aircraft

Key Technologies:

- Mode transition from turbine to DMRJ and from DMRJ back to turbine operations
- Extend high-end performance of off-the-shelf (OTS) turbines
- Extend low-end performance of Dual Mode Ramjet (DMRJ) common inlets and nozzles
- Goal: Takeoff to max Mach capable reusable engine ground demo
- Transition: DoD S&T organizations

Metrics:

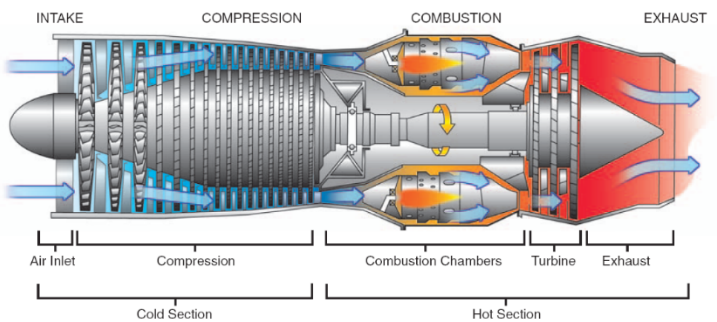
- Controlled propulsion system mode transition
- OTS turbine extended operations
- Dual Mode Ramjet (DMRJ) extended operations
- Sufficient thrust across full range of engine ops to meet vehicle acceleration needs

AFRE Potential Challenges and Progress

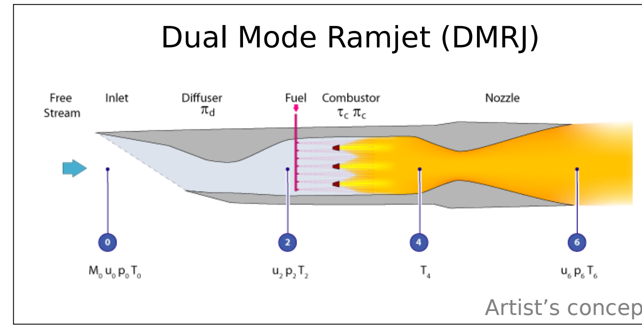
AFRE is a proposed new start

Technical Challenges:

Artist's concept



MODE TRANSITION



<u>OTS Turbine</u>

- Extended operability
- Thermal management in all phases
- Restart at high dynamic pressures and speeds

<u>Dual Mode Ramjet (DMRJ)</u>

- Extended operability
- Combustion stability
- Thermal management
- Ability to scale up

<u>Integration</u>

- Mode transition and controls
- Integrated inlets and nozzles
- Mass flow matching
- Thermal management

AFRE Challenges and Progress

Technical Challenges:

- Affordability
- Additively manufactured high-temperature structures
- Durability and damage tolerance
    - Additively manufactured components, subsystems, systems
    - OTS turbine with new environments
- Thermal management phases
- Restart at high dynamic pressures and speeds

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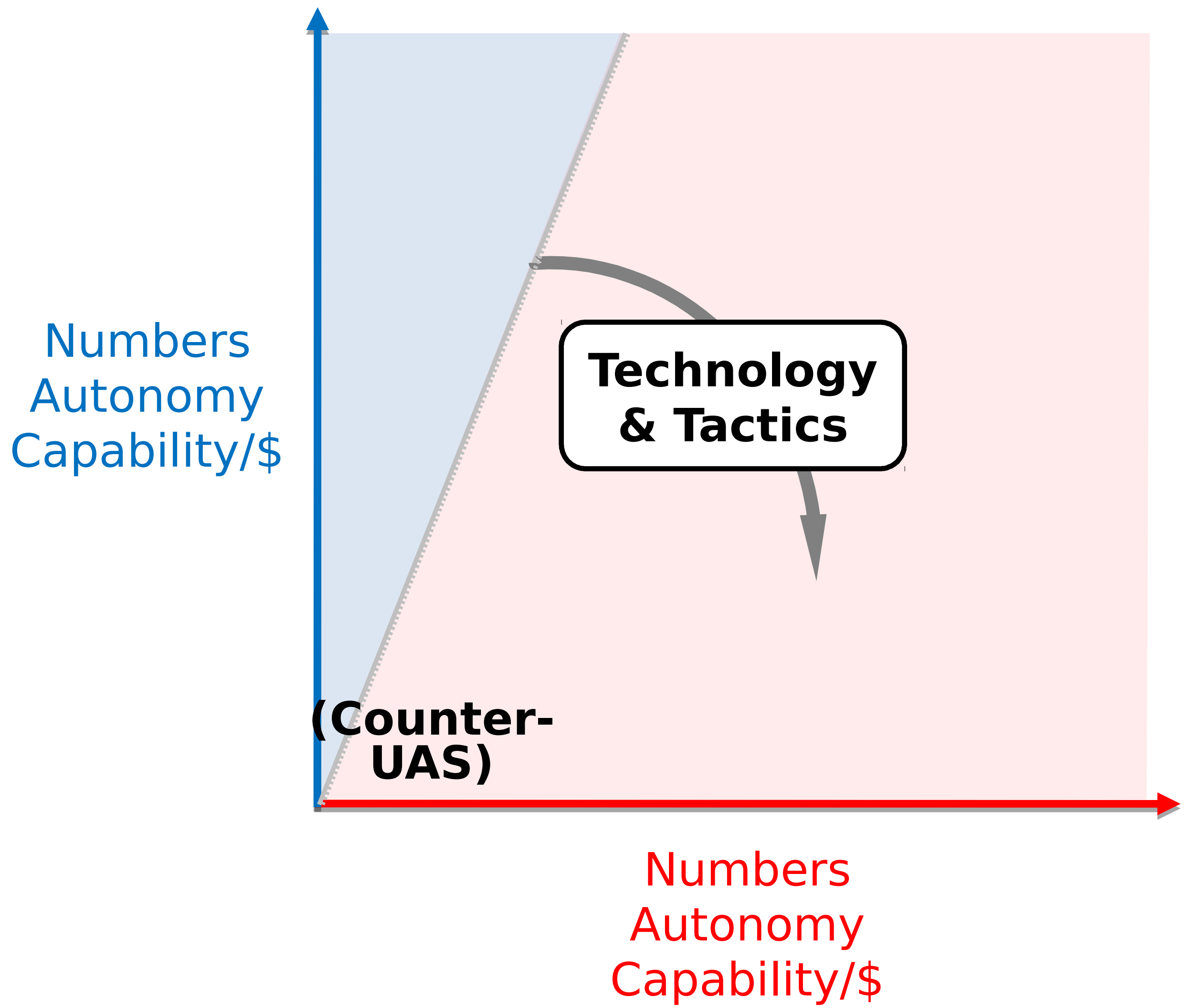
Dr. Timothy Chung, TTO Program Manager

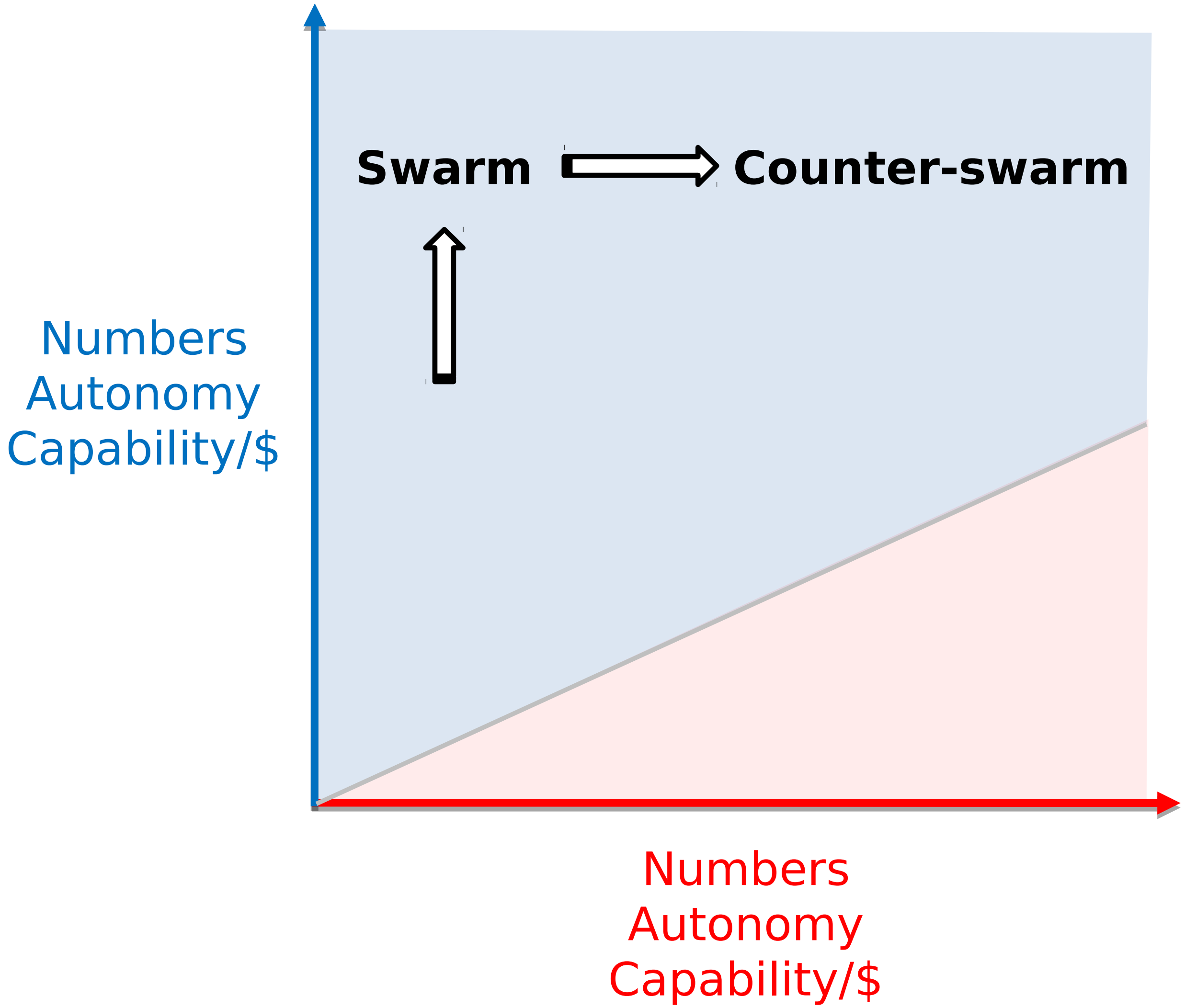
Briefing prepared for TTO Office-Wide BAA Proposers Day

April 20-21, 2016

Expanding the Envelope

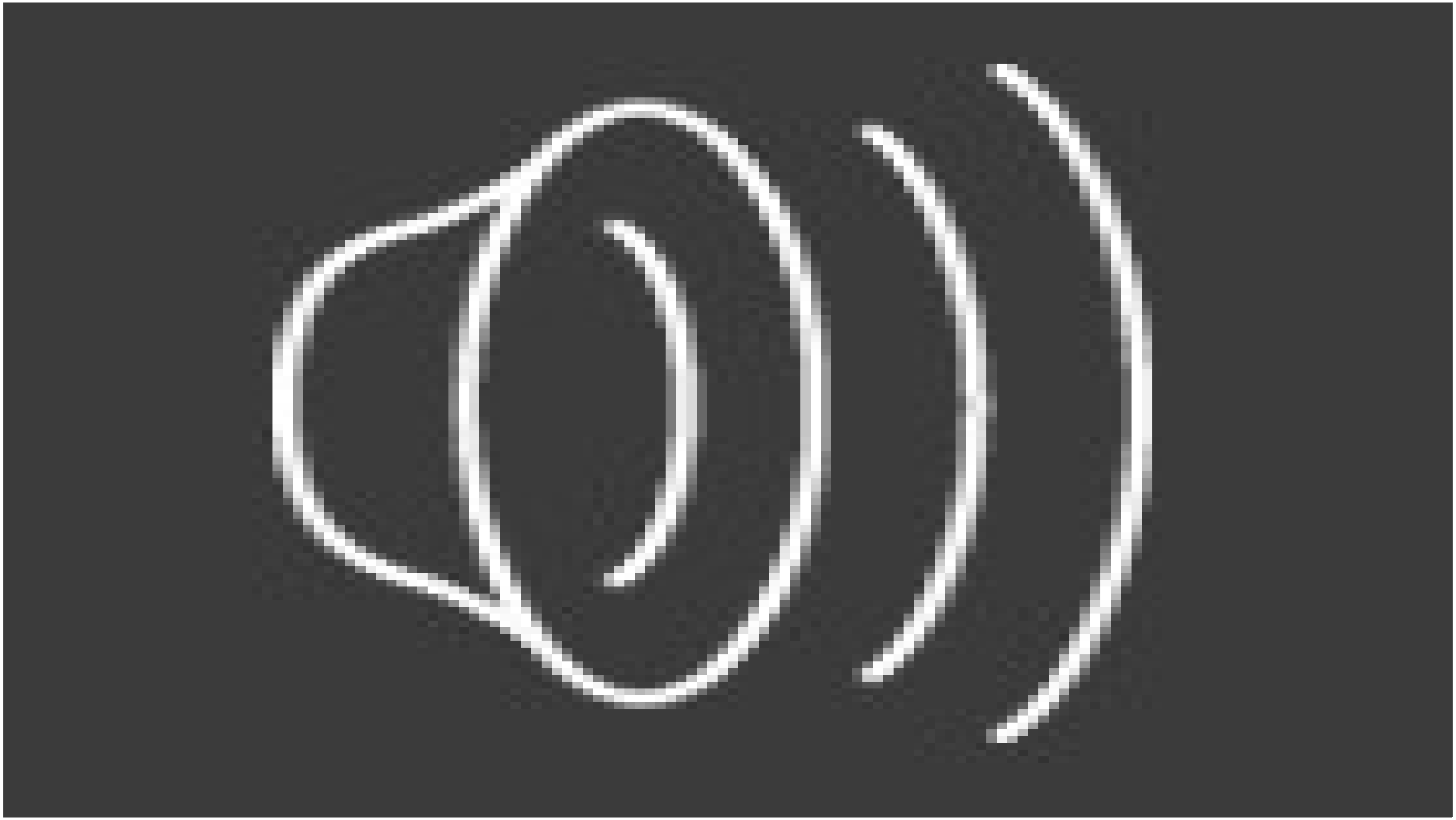


Expanding the Envelope



The whole is greater than the sum of its parts

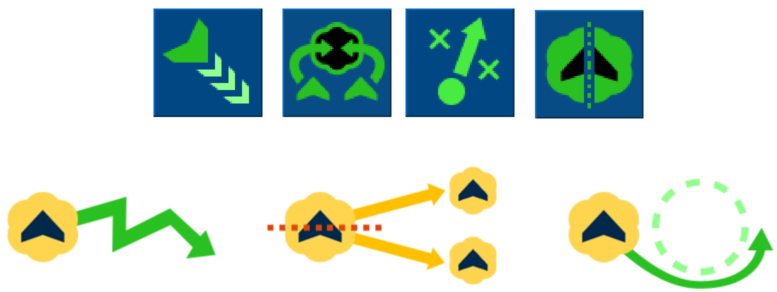
Quantity is a quality all its own



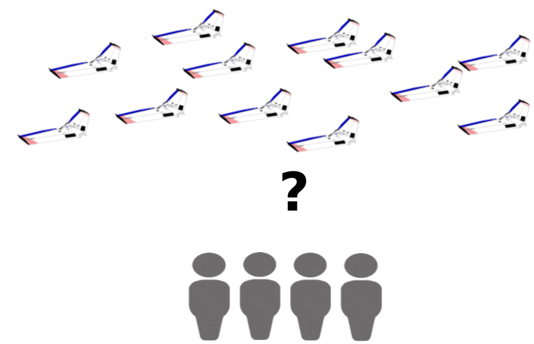
*Research not funded by DARPA

Core Swarm System Enablers

Novel concepts in swarm (and counter-swarm) tactics



New modalities for human-swarm teaming



Automation for improved swarm logistics

- Transport
- Maintenance
- Automated testing
- Mission updating
- Battery charging

New technologies for swarm networking

- Localized communication methods
- Minimized probability of detection
- Opportunistic communications

Key Highlights of Swarm and Counter-Swarm

- **Simultaneous offense** and **defense**
  - ◇ Focus on high-level tactical decisions
- **Heterogeneous** autonomous **swarms** for each team
  - ◇ Both fixed-wing and quadrotor platforms
- **Virtual scrimmages** through simulation
  - ◇ Facilitate accelerated development
- **Leverage open-source/hobby-grade** systems
  - ◇ Focus on advances in collaborative autonomy

Goal: Combine tactical insights with operational and logistical considerations

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TTO Proposers Day 2016

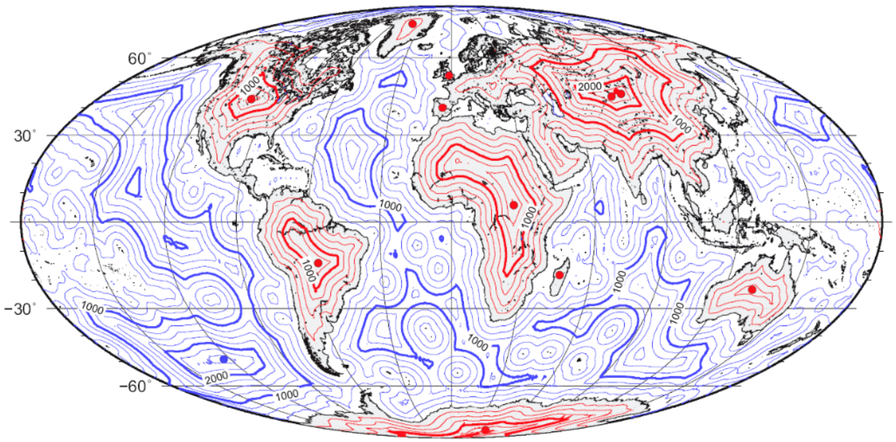
Dr. Daniel Patt, TTO Program Manager

Briefing prepared for TTO Office-Wide BAA Proposers Day

April 20-21, 2016

Tern Vision

Rapid global coverage



97% of world land area is < 900 nmi from coast
87% of world land area is < 500 nmi from coast

Left: Image/algorithm source: Poles of Inaccessibility: A Calculation Algorithm for the Remotest Places on Earth DANIEL GARCIA—CASTELLANOS

Enable distributed operations

Image source: US Navy via Wikimedia Commons

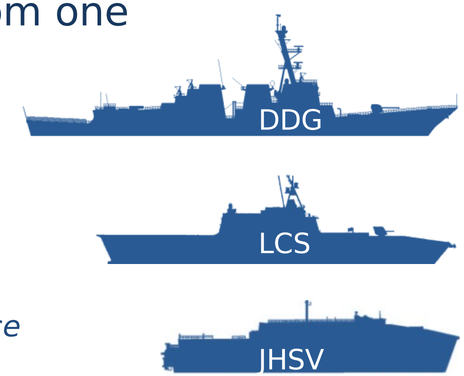
Image source: http://sphere3d.com/

Tern

Artist's concept

Achieve persistent airborne orbit with assets from one ship

Performance like land-based medium-altitude long-endurance (MALE) unmanned air systems (UAS)



Artist's concepts

Purpose:	**Key Technologies:**	**Metrics:**
• Demonstrate fixed-wing performance from smaller ships and austere settings, enabling robust, affordable access around the globe	• Launch & recovery from smaller ships in elevated sea states • Precision relative navigation and precise digital flight control technologies • Efficient speed and endurance for long-range operation • Operation in space- and personnel-constrained shipboard environments • Minimal host-ship modification	• Reliable launch and recovery of multi-ton aircraft from smaller ships (LCS, DDG, or other) in challenging operating conditions (Sea State 3+) • Air vehicle capable of delivering sufficient transit speed and endurance at medium altitudes for intelligence, surveillance, and reconnaissance (ISR) orbit to enable persistent coverage at 600+ nautical miles from host with 500+ pounds of payload

Tern Challenges and Progress

- DARPA and Office of Naval Research (ONR) working jointly on development and testing
- Completed preliminary design and risk reduction of a tailsitting, flying-wing aircraft with centerline propulsion
- Working on fabrication, integration, and demonstration of a full-scale demonstrator system

Artist's concept

Planned Schedule

FY2014	FY2015	FY2016	FY2017	FY2018	FY2019
Phase I Concept Design	Phase II Preliminary Design	Phase III Build, Integrate, Flight Test			

rn seeks to be the technology enabler for a new model of distributed air capabili

Interest Areas

- Novel systems architectures designed to enable fundamentally different
  ways of approaching problems, with high potential for game-changing impact

- Technology elements
  - Robotics
  - Human interfaces
  - Collaboration toolsets
  - System control
  - Verification
  - Manufacturing
  - Adaptive systems
  - Perception systems
  - Fault tolerance
  - Air, maritime, ground domains

Teaming constructs

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Mr. John Kamp, STO Program Manager

Briefing prepared for TTO Office-Wide BAA Proposers Day

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Blue Wolf

Artist's concept

Purpose:	Key Technologies:	Metrics:
• Develop and demonstrate an integrated unmanned undersea vehicle (UUV) capable of operating at speed-range combinations previously unachievable on current fixed-size platforms • Retain traditional volume and weight fractions for payloads and electronics • Program culminate in a series of at-sea demonstrations • Transition to Navy	• Novel concept designs • Revolutionary technologies for significant drag reduction, applicable over various range and speed combinations • Hybrid energy systems (two or more energy sources)	• Does not exceed current fixed-size platform length/weight/volume ◦ Fit within a 21"-diameter circular cylinder • Compatible with existing manned-platform safety requirements and future Navy technology developments • Navy-approved certification and integration with existing platforms within 30 months of contract award

Strategy

Accelerate Technological Maturity

- Reference architecture concept
- Model-based engineering
- Phased design, development and demonstration
- Design program for rapid technology development and integration
- At-sea demonstrations

Key: Address Certification Risks Early

- Requirements for safety approvals process
- Use Fleet approval and certification process model
- Technical engagement to understand design and operational constraints

Example Safety Considerations

Technologies with Greater Capability
Introduce New System Risks

- Longer range/higher speed = high-energy sources
  - Fire, explosion risks
  - Production of harmful/toxic by-products or combustible gases
  - Operational risks (inadvertent start-up)

- Go further and/or faster with the same or less energy = lift and drag reduction
  - Damage or failure during operation reduces performance
  - Personnel safety while in stowage or launching

Today

Goal: Navy Approval and Certification for At-Sea Demonstrations

- Established module level and system-level technical certification plans
- Detailed tasks and activities for identifying, evaluating, and mitigating module-level hazards by design
- Identifying and mitigate risks during “operations” such as stowage, handling, launching and recovery
- Engaging Navy technical authorities early

Interest Areas and Future Vision

Beyond Blue Wolf

- Propulsion technologies that enable
  - New missions or capabilities
  - Deliver an order of magnitude increase in key performance parameters (thrust, endurance, top speed, and time on target)

- Platform technologies that enable
  - A dramatic improvement in key operating parameters (speed and endurance in high sea state, crush and cruising depths, etc.)

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Briefing prepared for TTO Office-Wide BAA Proposers Day

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Anti-Submarine Warfare (ASW) Continuous Trail Unmanned Vessel (ACTUV)

Purpose:

- Build and demonstrate an unmanned sea surface vehicle with ocean-spanning range, months of endurance, and substantial payload
- Demonstrate high level autonomy for independent operations under sparse supervisory control
- Demonstrate game-changing approach to ASW track and trail mission
- **Demonstrate utility for additional Navy missions**

Key Technologies:

- Advanced autonomy for highly reliable surface collision avoidance while tracking evasive submarine target. Diverse set of ASW sensors for robust track and trail at standoff of up to a few miles
- **Advanced electro-optical/infrared (EO/IR) capability**
- **New payload technologies**

Metrics:

- Compliance with International Maritime Organization rules for collision avoidance at sea (COLREGS), **including vessel classification**
- Propulsive and maneuvering overmatch v. next generation diesel submarine threat; high-assurance target trail over entire operating envelope
- Endurance and reliability to complete 70+ day mission
- Unit production cost ~ $20M
- **Minesweeping at Navy objective performance level**

Items in green covered by Memorandum of Agreement (MOA) with ONR

ACTUV Program Technical Progress

<u>Autonomy:</u>

- Surrogate testing provides baseline for full-scale vessel
- Test plan is in development; International Regulations for Preventing Collisions at Sea (COLREGS) testing scheduled take up 2nd half of 2016
- **EO/IR detection and classification — Testing has started at System Integration Laboratory (SIL), integration on prototype vessel scheduled for 2017**

<u>Mission Systems:</u>

- ASW: Keel and bulb in construction; sensors will be delivered to San Diego for integration; at-sea testing scheduled for 2nd half of 2017
- **Mine countermeasures (MCM): Developing advanced magnetic influence sweep system for scheduled delivery in early 2017**

<u>Vessel:</u>

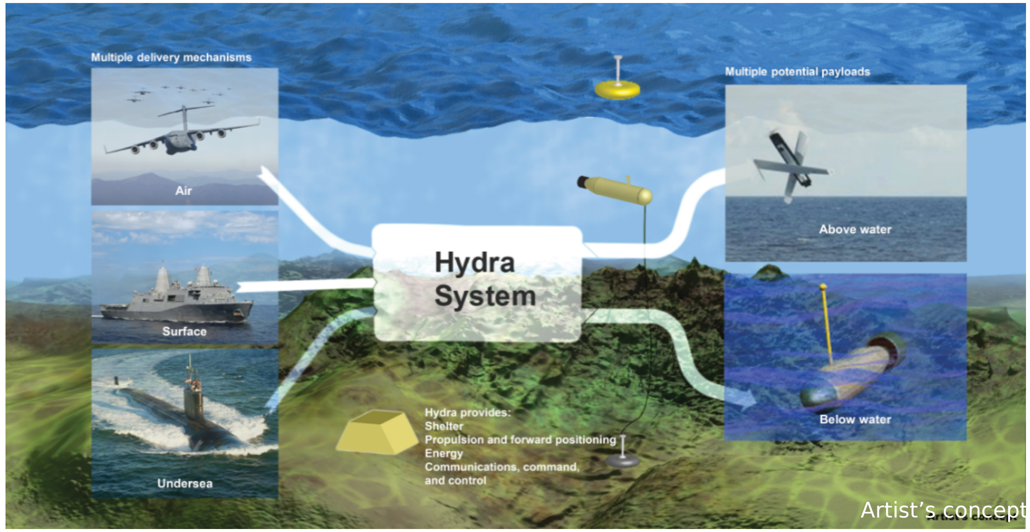
- Construction complete; launched into Columbia River on 27 January 2016; Builder's trials progressing well
- Christened "SEA HUNTER" on 7 April 2016 in Portland, OR
- **U.S. Navy Space and Naval Warfare Systems**

Items in green covered by MOA with ONR

ACTUV Program Future Challenges

- Completion of Builder’s Trials, baseline performance testing, autonomy verification testing, COLREGS testing, and acceptance of SEA HUNTER by DARPA
- Development, delivery and testing of DARPA and ONR payloads for the Memorandum of Agreement (MOA)-sponsored Extended Test Phase (ETP) (FY2016 to FY2018)
- Identification of other potential payloads and missions suitable for a large unmanned surface vessel

Hydra



Artist's concept

Purpose:	Key Technologies:	Metrics:

• Develop and demonstrate an unmanned undersea platform with associated payloads able to be deployed into operational environments and employed in innovative ways
 	
• End state is the development of a versatile modular enclosure, with payload modules ready for early transition and operational employment
	• Modular Enclosure
	  • Command, control and communications (C3), autonomy, ballast and control
	
	• Undersea payload
	  • Docking in currents
	  • Free space transfer of power and data
		• Ability to operate at depths for 180 days, air independent
		
		• Launch and recover undersea vehicles in 2-knot current, generate multiple sorties reliably
		
		• Flexible for a variety of missions

Hydra Program Future Challenges

- Undersea testing of the modular enclosure that includes submerging and surfacing, long-duration underwater operations and extensive communication testing
- At-sea testing of capture and docking mechanisms for UUVs
- Demonstrating undersea energy and data transfer
- Other payloads?
- Integration and testing of the full Hydra system

Other Potential Research Ideas

- MAD Swarm — The integration of magnetic sensors and other sensors on a swarm of autonomous UAVs launched from small warships to provide a new ASW search capability to the battlegroup
  - Objective is to demonstrate swarm capability and provide a new operational capability
  - Key technical areas include: aircraft, sensor integration; intelligent search behavior; resilient communication architecture; reduced manning

Artist’s concept

- Powered Parafoils — Develop and field a simple, low-cost aircraft that provides long-duration and large-lift capability able to perform ISR, strike and logistics missions
  - Objective is to develop an inexpensive, multi functional capability operated by multiple Services
  - Key technical areas include: Autonomous operations, hybrid propulsion and a clandestine capability

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Dr. Chris Warren, TTO Program Manager

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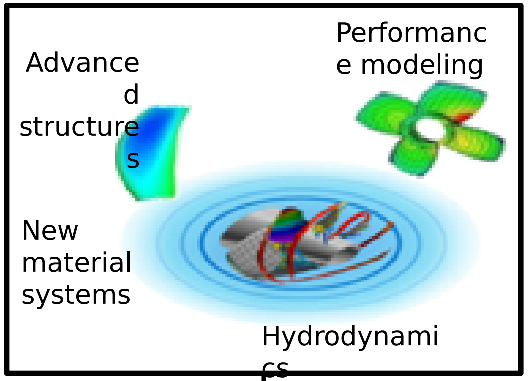
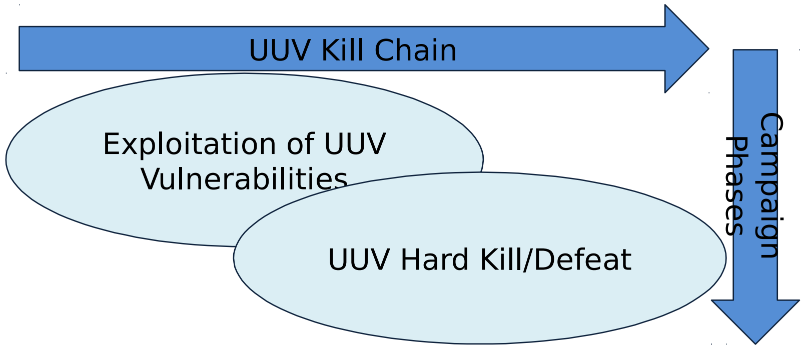
Hybrid Multi Material Rotor Full Scale Demonstration (HyDem)



Artist's Concept

Purpose:	Key Technologies:	Metrics:
• Dramatically improve U.S. Navy submarine superiority by applying breakthroughs in materials, material system technologies, and multi-disciplinary design methods to a Virginia-class submarine rotor, a critical component in submarine performance • Design, manufacture, and supply the Navy with a novel component for integration into a new construction Virginia-class submarine	• Multi-material characterization to include laminate and interface joint design, manufacturing processes, structural adequacy, and UNDEX performance • The Navy would evaluate the novel component in sea trials, and at the Navy's discretion, integrate into the future fleet	• Weight • Cost • Multi-disciplinary performance

Open Ocean Counter Unmanned Underwater Vehicle (OOCUUV)



Develop novel technology solutions to detect and negate adversarial UUVs

Purpose:	Key Technologies:	Metrics:
• Identify and develop technology solutions for exploitation of adversarial UUV vulnerabilities, with emphasis beyond port/harbor defense • Determine effectiveness of technologies by conducting demonstrations at a Government range • Leverage results to inform and conduct preliminary designs of full-scale prototype systems	• Seeking solution for detection and negation of UUVs • Detection — means of detecting small signatures emitted by a UUV such as, but not limited to: acoustic, electromagnetic, etc. • Negation — means of negating a UUV or its mission such as, but not limited to: jamming, kinetic hard kill, etc. • Key technology enablers would be demonstrated in a relevant environment	• Detection range • Area search rate • Probability of detection • Probability of false alarm • Technology enabler cost • Projected aggregated system cost

Interest Areas and Future Vision

- Maritime technologies that enable significant performance increases
- Cost-advantageous technologies to shift cost asymmetry in favor of the United States
- New, novel, cost-effective platform approaches to today's missions
- Non-lethal approaches to projecting power in the maritime domain

- Underwater platforms and platform technologies
- Maritime propulsion technologies
- At-sea energy harvesting, scavenging, management
- Advanced hydrodynamic concepts

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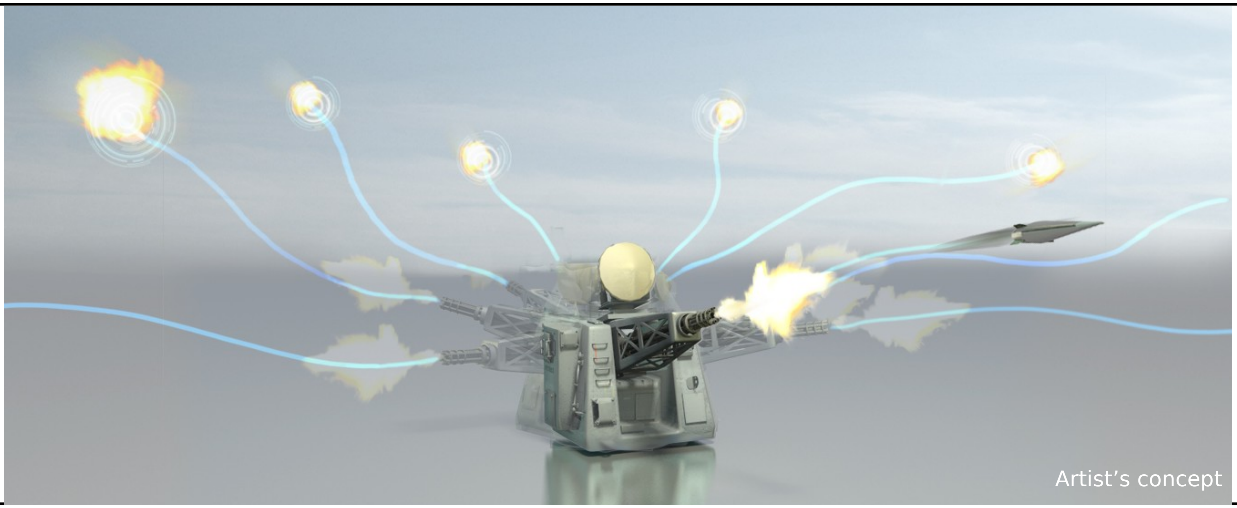
Multi-Azimuth Defense Fast Intercept Round Engagement System (MAD-FIRES)



Artist's concept

Purpose:	Key Technologies:	Metrics:
• Provide a highly capable guided projectile that is able to withstand the gun launch environment and achieve greatly enhanced accuracy • Address threat of attacks by unmanned vehicles, missiles, small planes, fast in-shore attack craft and other platforms posing a perennial, evolving and potentially lethal threat to ships and other maritime vessels	• MAD-FIRES aims to advance fire-control technologies, medium-caliber gun technologies and guided-projectile technologies, enabling simultaneous engagement of multiple targets	• Multiple simultaneous threat engagements • Missile-like precision in a miniature package • In-flight target tracking • Engagement of fast targets • Re-engagement of surviving targets • Decreased per-engagement cost • Applicability to all Services and many missions

MAD-FIRES Challenges and Progress

- Lethality
  - Small interceptor must defeat much larger target
  - ARDEC expertise used to define projectile requirements for threat defeat

- Maneuver — total, maximum, and time constant
  - Threat maneuver requires special attention to energy management
  - Executing detailed component development for timely controllability

- Gun packaging
  - Projectile must survive gun launch environment
  - Conducting Phase 1 gun launch tests of components

Interest Areas and Future Vision

- Additional applications (offensive and defensive) for guided bullets
  - Army Stryker 30 mm upgrade and SOCOM AC-130 — Anti-personnel and light armor
  - Counter-unmanned aerial systems
  - Counter-rocket, artillery, and mortar

- Projectile risk reduction
  - Gun-hardened component technologies
    - Rocket motors, inertial sensors, control actuators
    - New warhead technologies (small, multi-function)
  - Technologies that reduce projectile requirements and development risks
    - Ship-based navigation (precision fire control)

- Navy fleet protection
  - Harbor protection
  - Countermine warfare
  - Hypersonic weapon defense

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TTO Proposers Day 2016

Major Christopher Orlowski, Ph.D., TTO Program Manager

Briefing prepared for TTO Office-Wide BAA Proposers Day

April 20-21, 2016

A Multi-Domain Operational Environment

Among the people

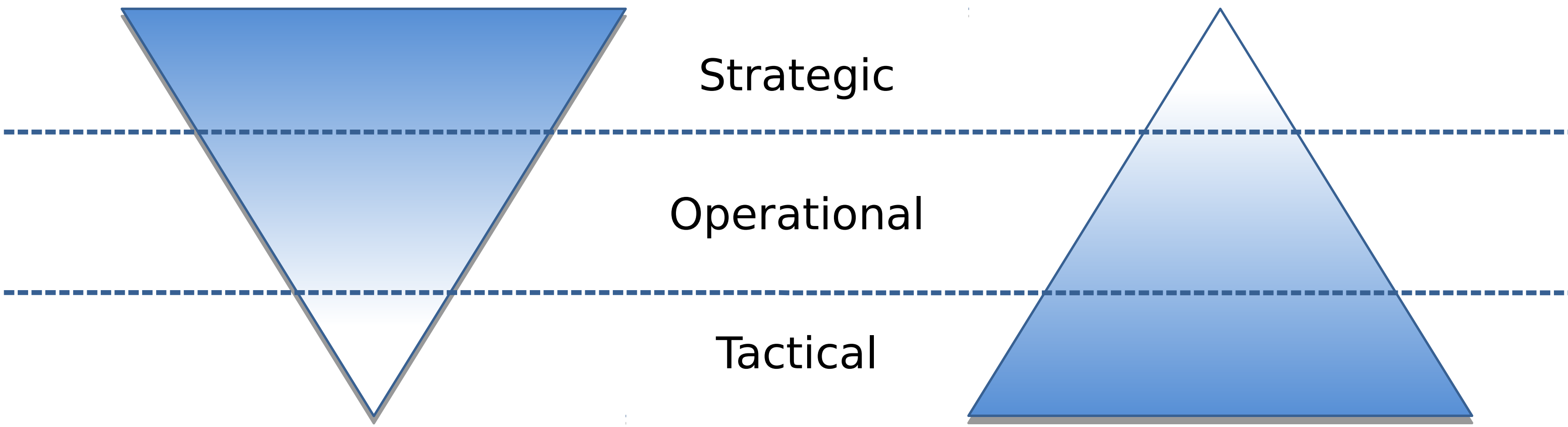
Complex, urban terrain

Underground/indoors

Squads operate where an adversary can readily exploit the physical, electromagnetic spectrum, and cyberspace domains for movement and communications and in an increasingly connected global society that requires precise operations in all domains

Create a Paradigm Shift for Combined Arms

Precision Effects and Intelligence Capabilities Today	Precision Effects and Intelligence Capabilities Needed Tomorrow[1]



Squads designed for linear, deterministic, and single-domain operations

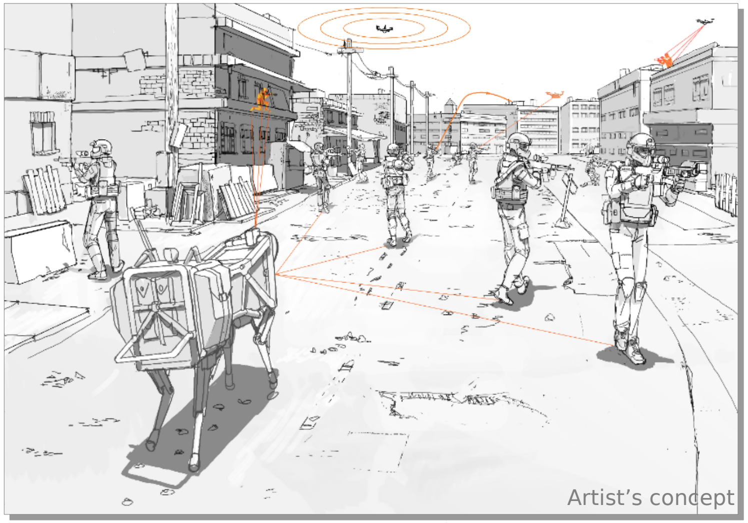
Squad X

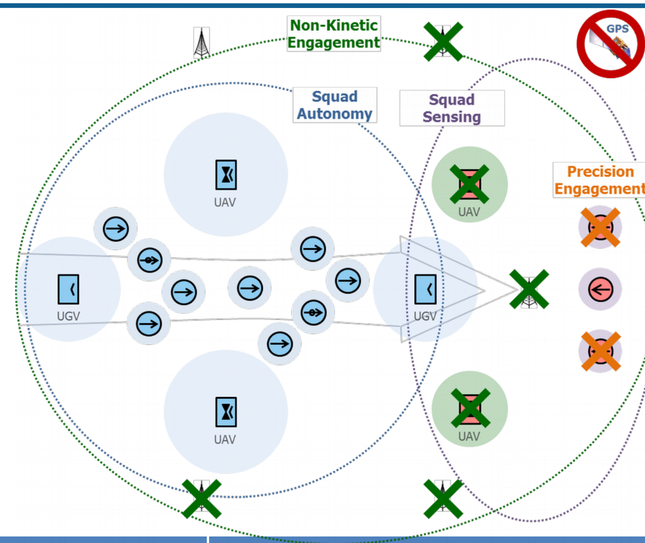
Squads designed for nonlinear, stochastic, and multi-domain operations

Build the foundation of the next generation of combined arms

1 Adapted from War From the Ground Up, Emile Simpson, Oxford University Press, 2012

Squad X Core Technologies (SXCT)





Purpose:

- Develop new organic technologies for the rifle squad that:
  - Give dismounted squads enhanced situational awareness
  - Enable them to shape and dominate their battlespace
- Provide a basis for future system development efforts through modeling, simulation, and baseline experimentation

Key Technologies:

- The four technical areas are: Precision Engagement, Non-kinetic Engagement, Squad Sensing, and Squad Autonomy
- The program end state is a set of capabilities (live and in hardware-in-the-loop simulation) that individually demonstrate significant potential to augment the dismounted squad
- Potential transition partners include: USA Maneuver Center of Excellence, USA RDECOM, PEO Soldier, Office of Naval Research, Marine Corps Warfighting Laboratory, Marine Corps Systems Command, and Special Operations Command

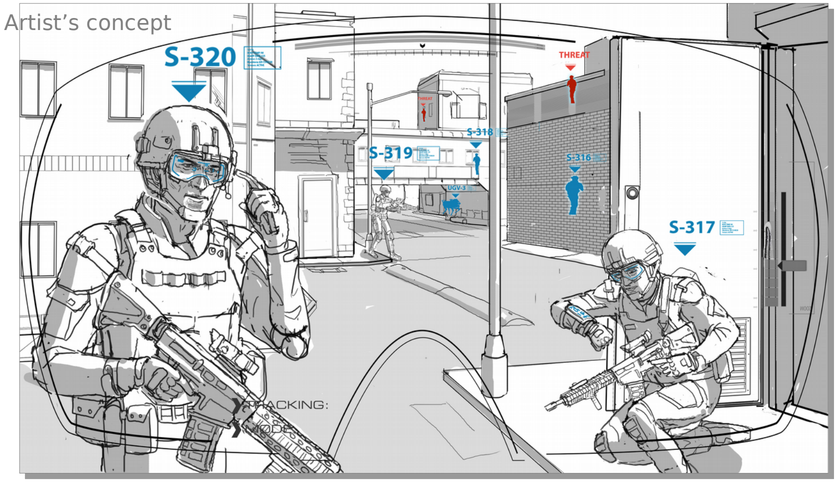
Metrics:

- Program metrics vary by Technical Area

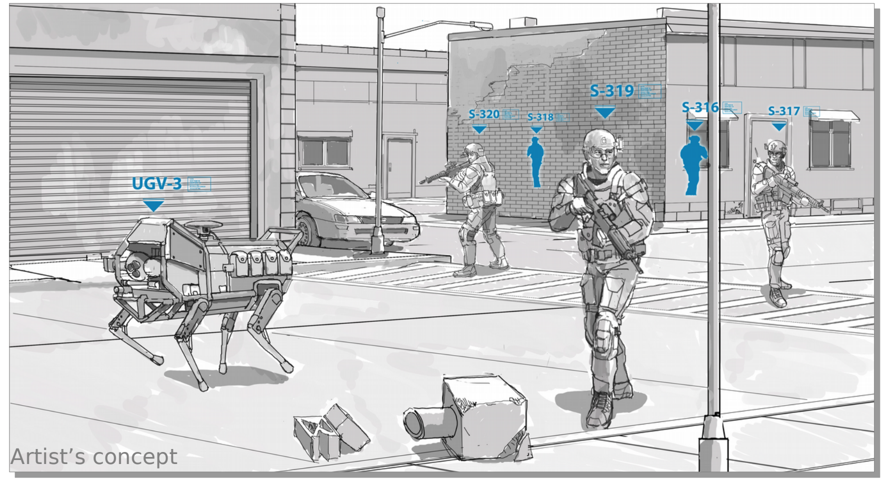
Precision Engagement		Non—Kinetic Engagement	
Accuracy	2 m CEP	Squad Speed	≥ 2 m/s
Mass	≤ 1.0 kg	Mass	≤ 900 g
Recoil Energy	≤ 70 joules	Volume	≤ 500 cm^3

Squad Sensing		Squad Autonomy	
Accuracy	0.9	Abs. Position	≤ 6 m
Squad Speed	≥ 2 m/s	Interventions	0
Mass	≤ 350 g	Mass	≤ 350 g
Volume	≤ 200 cm^3	Volume	≤ 200 cm^3

Squad X Experimentation (Squad X)



Artist's concept



Artist's concept

Purpose:

- The objective of the Squad X Experimentation program is to design, develop, integrate, and validate system prototypes that enable next-generation combined arms for the dismounted squad
- The resulting Squad X systems would maximize squad performance in increasingly complex, multi-domain operational environments

Key Technologies:

- Enable the squad to understand their entire operational environment: physical, electromagnetic spectrum, cyberspace
- Optimize use of the squad's limited physical, cognitive, and material resources
- Synchronize fire and maneuver in the physical, electromagnetic spectrum, and cyberspace domains
- Potential transition partners include: USA Maneuver Center of Excellence, USA RDECOM, PEO Soldier, Office of Naval Research, Marine Corps Systems Command, and Special Operations Command

Metrics:

- The System Prototyping phase seeks to demonstrate successful execution of missions with synchronized fire and maneuver against line-of-sight threats 300 meters or greater from the squad
- The System Development Phase seeks to execute a capstone experiment with multiple Squads X; Performer(s) will be expected to demonstrate synchronized fire and maneuver against non-line-of-sight threats at distances greater than 1,000 meters from the squad

Ground X-Vehicle Technologies (GXV-T)


Artist's concept

Purpose:	Key Technologies:	Metrics:
• Develop next-generation ground platform technologies that improve expeditionary mobility and combined tactical and strategic factors without sacrificing survivability • Break the 'more armor' paradigm by enabling a future design space not dominated by heavy armor solutions • Enable increased capability for small units	• **Mobility:** Advanced in-hub-wheel motors, morphing tracks, advanced suspensions • **Agility:** Movable armor • **Crew Augmentation:** Aircraft cockpit-based displays, multiple simultaneous battlefield perspectives, co-driver support • **Signature Management:** Reduction in vehicle signatures • Potential Transition partners: TARDEC	• Reduce inaccessible terrain to less than 5 percent • Increase off-road speed to 120 kph • Protection against rocket-propelled grenades (RPGs) from 100 m and anti-tank guided missiles (ATGMs) from 1,000 m • Local 360-degree situational awareness to a distance of 1,000 m at tactical speed • Decrease probability of detection, increase time to engage for enemy

Area of Interest

Removing the burden of holding the horses by turning those horses into enablers

Increasing the capability of riders while mounted on their horses

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Dr. Bradford Tousley, TTO Office Director

Briefing prepared for TTO Office-Wide BAA Proposers Day

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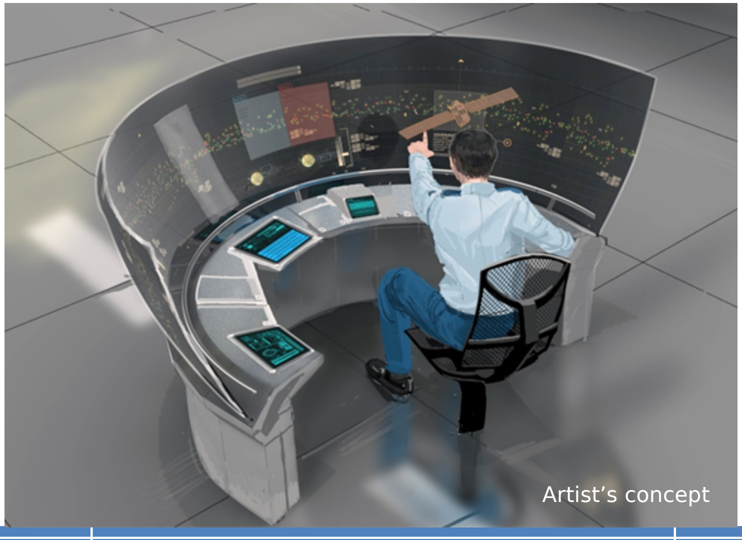
Hallmark



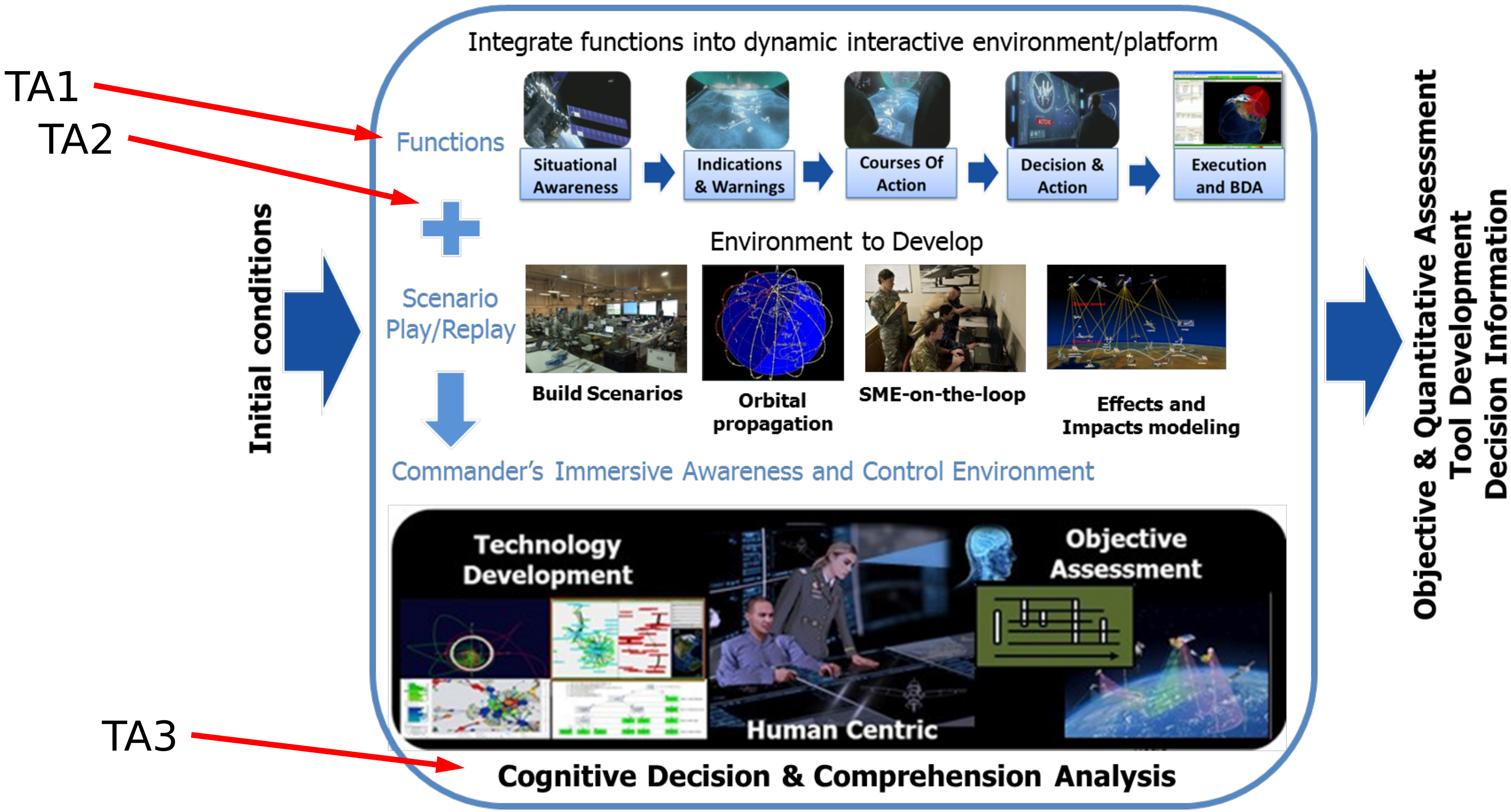
Purpose:	Key Technologies:	Metrics:
• To provide a **test bed** to develop and demonstrate the full range of space situational awareness (SSA) and command and control (C2) capabilities to enhance scenario comprehension for a commander • To **reduce** the **time** required to resolve incidents involving space assets • To **develop** the **technologies**, tools, modeling and simulation, databases, and processes to flow tools together to achieve an effective structure • To develop **human-centric** approaches to SSA and C2 with qualitative and quantitative assessments of live demos	Hallmark seeks to demonstrate **tools, algorithms and integrated architecture** for SSA, C2, indications & warning (I&W), and course of action (COA) development and execution via a **human-centric environment** that intends to provide the ability to perform operational evaluations by three roles: (1) Space operator subject matter experts (SMEs) on console (2) Retired general officers (GOs) acting as commanders (3) Cognitive analysts observing and interacting with operators, commanders, and technologists to improve comprehension Goal: Direct transition of tools to AFSPC and National Reconnaissance Office (NRO)	Phase demos would evaluate key SSA, C2, I&W and COA milestones Demo 1: End-to-end SSA/C2 functionality that manually connects all required tools to complete the SSA/C2 mission in 10 total hours of demonstration Demo 2: End-to-end SSA/C2 functionality that automatically connects all capabilities in an integrated system, within 5 hours Demo 3: End-to-end SSA/C2 functionality that automatically connects all capabilities in an integrated system, within 2.5 hours

Hallmark Challenges

- Increased awareness of a decision—maker's options through the creation of an effective Common Operating Picture (COP) from multiple data sources, including:
  - Awareness of option pre-conditions, post-conditions, risks, decision points, confidences, time and resource constraints, and more;
  - Multi-domain interactions required for the totality of the battle space (space, air, land, sea, cyber) and extra-military actions (diplomatic, commercial)
- Informed models of adversary intent through the combination and extrapolation of fused information, including:
  - Hypotheses of anomaly "meaning" and adversary expected/potential behavior based on analytics over large historical data sets;
  - The support of hypothesis-based tasking to confirm and respond to adversary intent
- Dynamic course-of-action (CoA) customization/selection/execution by transforming static course-of-action capability with comprehensive modeling and simulation (M&S) at the operational level, including:
  - Tactical and strategic M&S to support both time- and resource-sensitive as well as non-critical situation maintenance for end-to-end scenarios
- Novel ways to present complex information from the space domain

Program Composition

- TA1 — Tools and Capabilities Development
- TA2 — Testbed Development and Integration
- TA3 — Demonstration and Evaluation

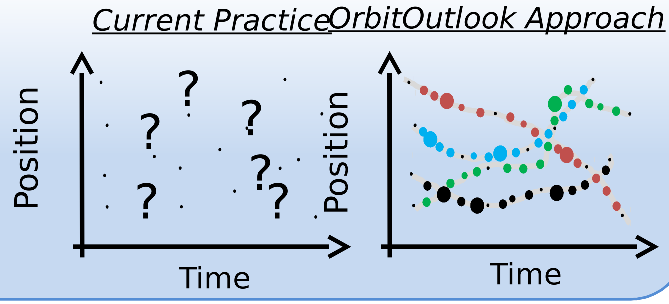


Artist's concepts

OrbitOutlook (O2)

Data-Centric

- **OrbitOutlook** seeks to demonstrate non-traditional sensor utility by automating uncertainty and confidence estimations to enable real-time decision making



Purpose:	Key Technologies:
• To develop and demonstrate a data-service oriented SSA framework. O2 is investigating two areas: • Advanced space surveillance data sources to better detect, track, and characterize space objects not adequately monitored by current sensors • Space surveillance data processing and optimization algorithms to increase space domain awareness, threat mitigation, and overall space safety	• Technologies to integrate civil, academic, industry, and non-traditional government sensors for space domain awareness • Algorithms to verify information assurance and data quality • Development of additional I&W and characterization algorithms • Potential transition partners are AFSPC, NASA, FAA, industry, and/or other Agencies

Metrics:

	Current SSN	OrbitOutlook Objective
Metric Accuracy	3 km	100 m
Radiometric Precision		+/- 5%
Radiometric Accuracy		+/- 20%
I&W Timeliness	< 4 weeks	< 6 hours
I&W Accuracy		99%
$/Byte Relevant Data	$0.05	$0.001
GB/year Relevant Data	10	~30
Total Cost	$500M	$275M

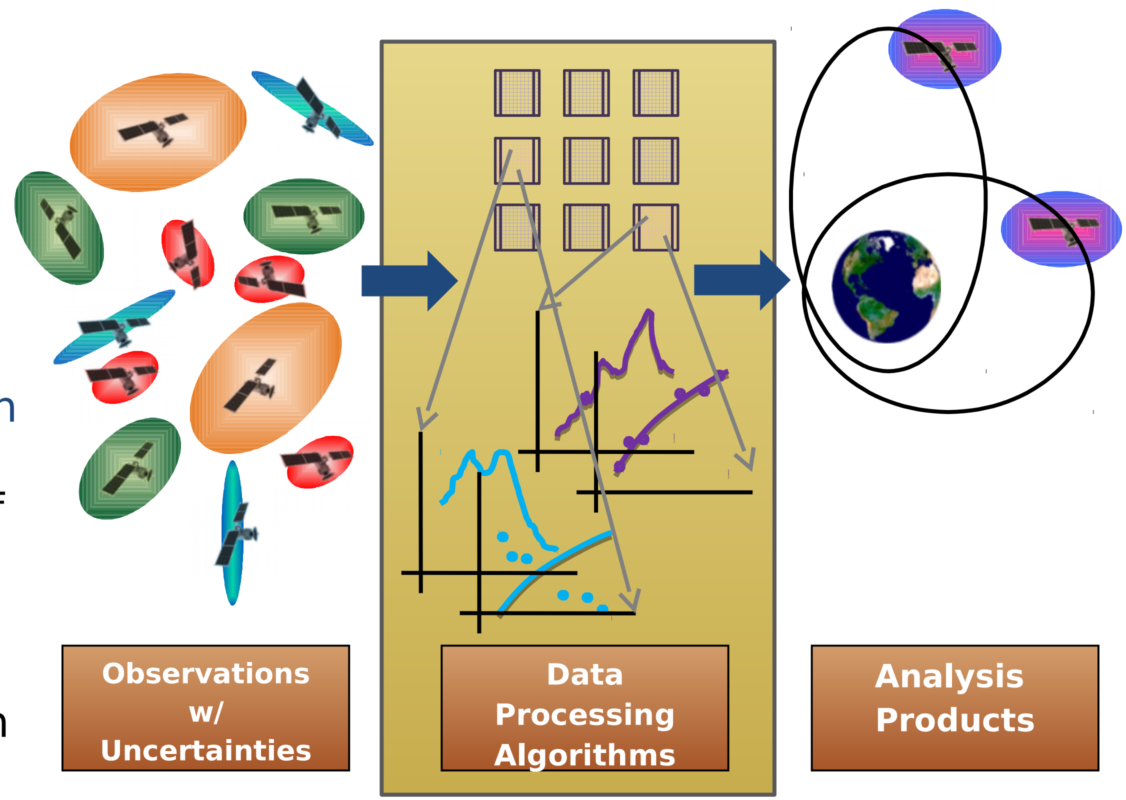
Performers: Lockheed Martin ATL, IAI/PDS, ADS, ExoAnalytic, Rincon, SRI

OrbitOutlook at a Glance

- O2 operations consist of two basic steps
  - *Data collection*
    - Level A: Observation Reduction
      ("What data can be gleaned from site/sensor observations?")
  - *Data processing*
    - Level B: Data Validation

      ("What is the quality of the data?")
    - Level C: Data Exploitation
      ("What information can be distilled/mined from the data?")

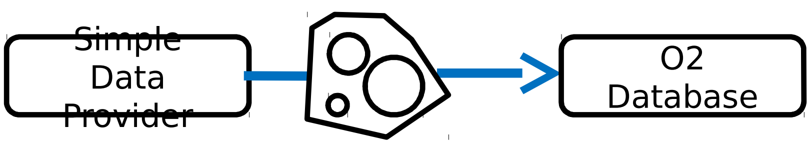
How Is OrbitOutlook Achieved?



O2 Progress: Data Connectivity Construct

- "Simple Data Connectivity"
- Submits data to O2 in native/local format—without translating the data to O2 format

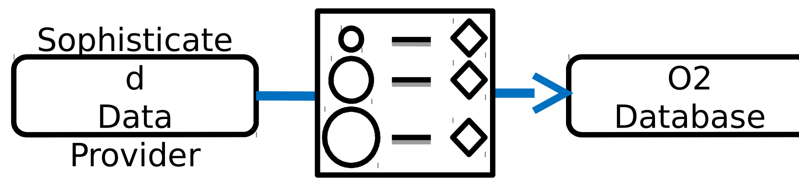
Non-O2
Formatted Data



- Using this submission method, O2 requires a *translation script* so the database can read and interpret as-provided data
  - All Source General Data Receiver (ASGDR)
- Accomplished on O2 side via data broker

- "Sophisticated Data Connectivity"
- Submits data to O2 in the O2 format —translate their data to map to the O2 Data Dictionary fields

O2
Formatted Data



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TTO Proposers Day 2016

Mr. Jess Sponable, TTO Program Manager

Briefing prepared for TTO Office-Wide BAA Proposers Day

April 20-21, 2016

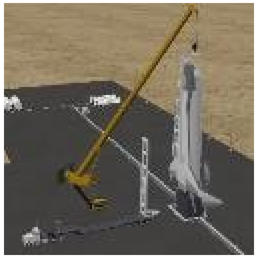
Experimental Spaceplane (XS-1)

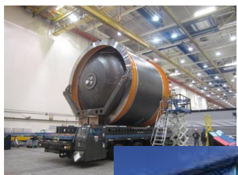
Purpose:	Key Technologies:	Metrics:
• Design, fabricate and flight test a reusable first-stage XS-1 spaceplane ✓ Mature critical technologies ✓ Integrate & validate lean ops ✓ Enable routine and low-cost access to space • Transition capability to commercial, DoD, and civil stakeholders	• Design and system integration enabling "aircraft-like" operations • Highly integrated airframe • Robust, rapid-turnaround thermal protection & management systems • Advanced GN&C and automation • Reusable, long-life & affordable propulsion	1. Reusable 1st stage, expendable upper stage(s) 2. Design the objective system for recurring cost < 1/10th Minotaur 4 > 3,000 lb payload < $5M per flight 3. Fly XS-1 10 times in 10 days 4. Launch demo P/L > 900 lbs once

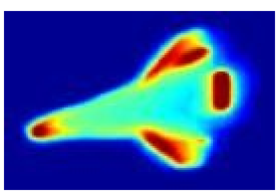
XS-1 Phase 1B
Aug 2015 — July 2016

Technology Risk Reduction
Propulsion, TPS, cryogenic tanks, GN&C and Ground Ops

Phase 1 Technical Challenges & Progress







"Aircraft-like" operations

- Reliable, maintainable, supportable, minimum manpower
- Incremental flight test, like aircraft
- Pioneered by DC-X & commercial sector, KSC focus on high ops tempo launch

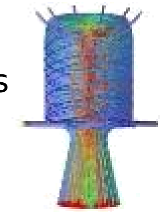
Long-life airframe & structures

- Substantial Air Force and NASA investment in composite airframe technologies
- Reusable composite cryotanks extensively tested, full-scale testing in progress

Aero-thermodynamics

- Plethora of modeling, simulation and design tools driven by PC
- Thermal environment much less stressing than for the Space Shuttle

Propulsion options growing



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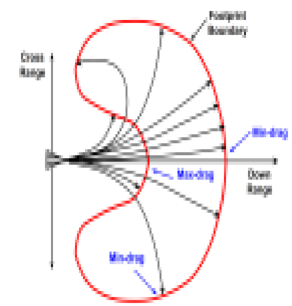
- Long-life, reusable engines
- Propulsion cycles selected for cost & operability vs performance
- Demonstrated robust engines and technologies

Operable subsystems

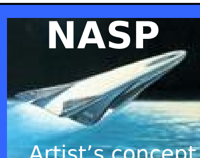


- Proven adaptive GN&C; anywhere, anytime autonomous abort
- Leverage many existing aircraft components and equipment
- Multiple successful AFRL contracts

Low-cost upper-stage options

- Minimize stages, parts count & complexity
- Minimize dry weight/size
- Low-cost manufacturing processes
- Safe and available propellants
- Minimum-cost design

TRL ~3



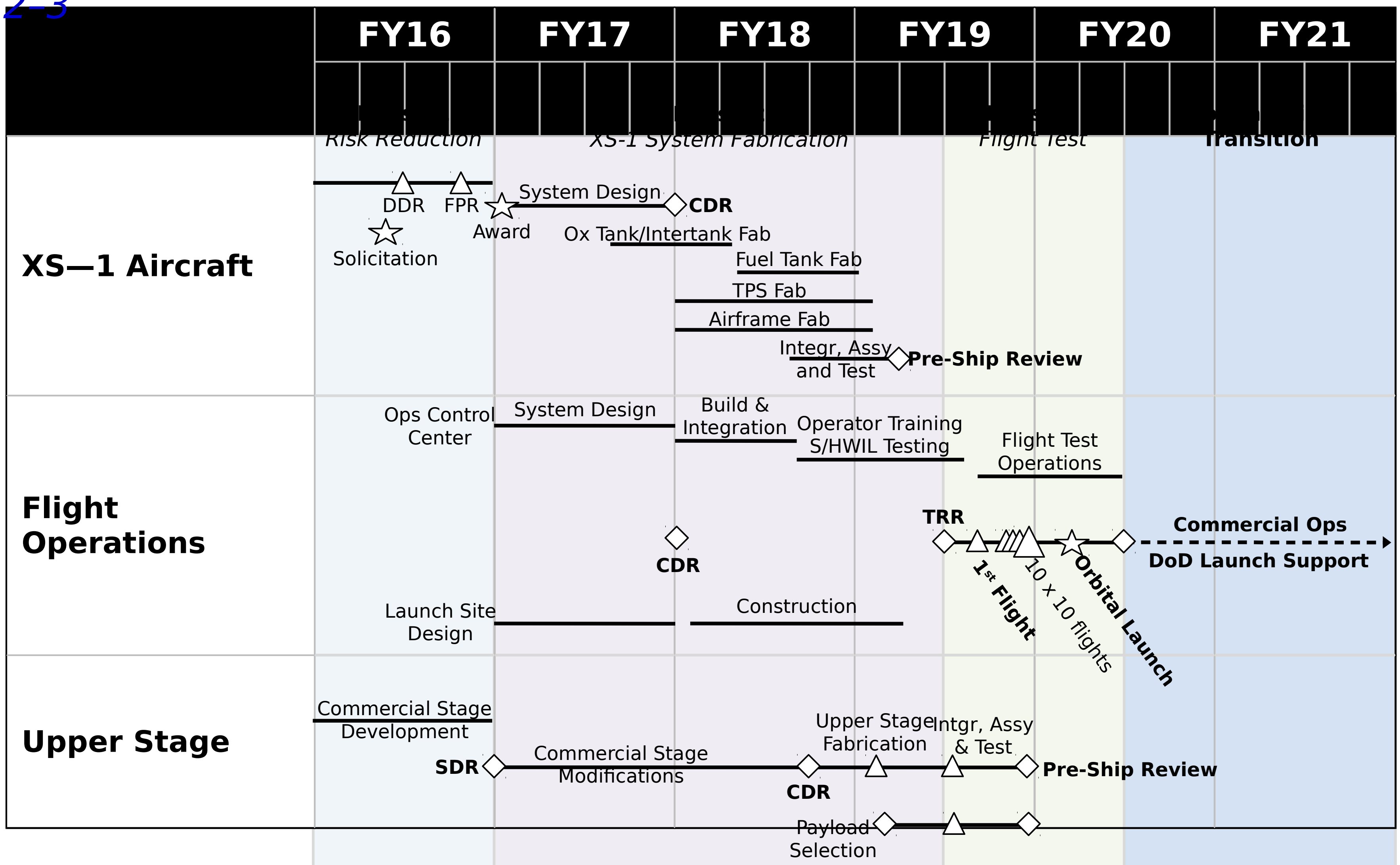
TRL ~2

TRL 3 at

Past programs began relying on immature technology AND over-specified the requirements (SSTO, scramjets, heavy lift, crewed, etc.)

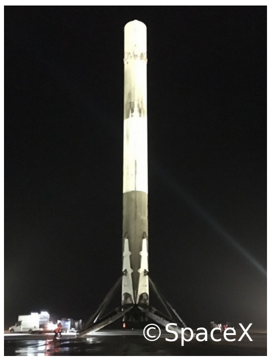
Planned Schedule/Milestones/Funding

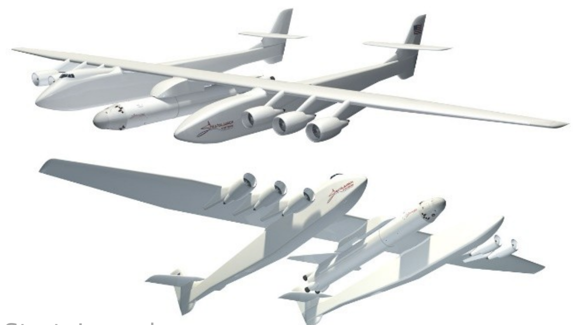
Full and Open Competition for Phase 2–3



Interest Areas and Future Vision

- Space launch systems
- Incentivize next-generation commercial launch systems





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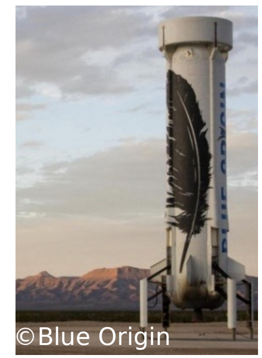

- Development of next-generation rocket propulsion
- Space systems, small distributed satellites
- Solar-electric propulsion
- Advanced physics for propulsion and energy

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TTO Proposers Day 2016

Dr. Lindsay Millard, TTO Program Manager

Briefing prepared for TTO Office-Wide BAA Proposers Day

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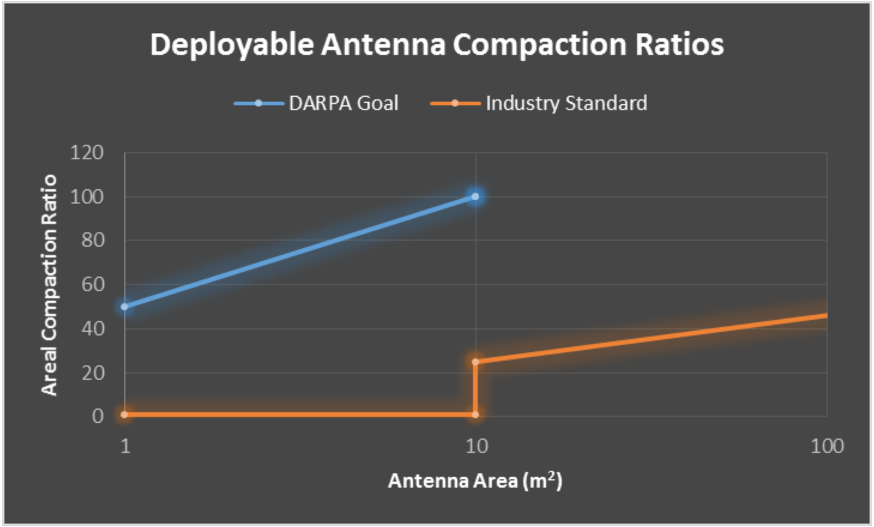
RNET: Microsatellite RF Technology

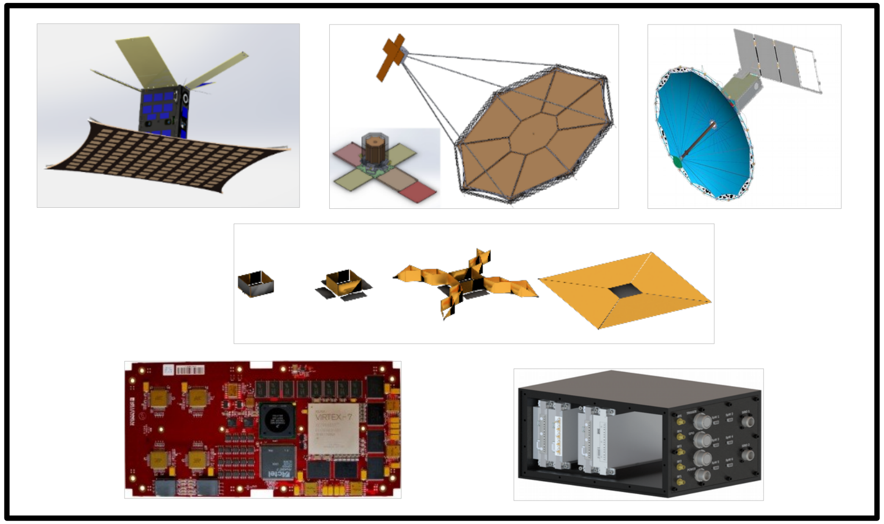
Purpose:	Key Technologies:	Metrics:
• To develop RF remote sensing and communications technology for microsatellite platforms by developing deployable apertures and low-size, -weight, and -power (SWaP) software-defined radio (SDR) technology	• Highly compact, deployable, large antenna apertures from nano- to microsatellites • Low-SWaP, high-performance SDRs • On-orbit or equivalent demonstration of the key technologies • Envisioned transition partners: Small satellite community including SMDC, ORS, USAF, other DoD Agencies, and commercial industry	Aperture: • > 4 GHz w/ > 200 MHz bandwidth • > 10 m^2 with > 100X areal compaction ratio • < 15 kg • >100 W peak power input SDR: • < 50 W peak, < 100 mW standby • > 10 GOps/W • < 5 kg • > 200 MHz instantaneous bandwidth

Microsatellite RF Technology Challenges and Progress

Highly Compact Deployable Antenna Technology
- Highly compact reflector with high-power feed
  - Antenna range and environmental testing planned
- Body-mounted Wideband Reflectarray
  - Design, build, and test of 4 m^2 pathfinder antenna system
- Offset Reflectarray
  - Design, build, and test of 4 m^2 proof-of-concept
- Membrane-based Micro-strip Array
  - Conceptual design for ~1 m^2, 10 W array completed
  - Plan to fly design on 6U cubesat

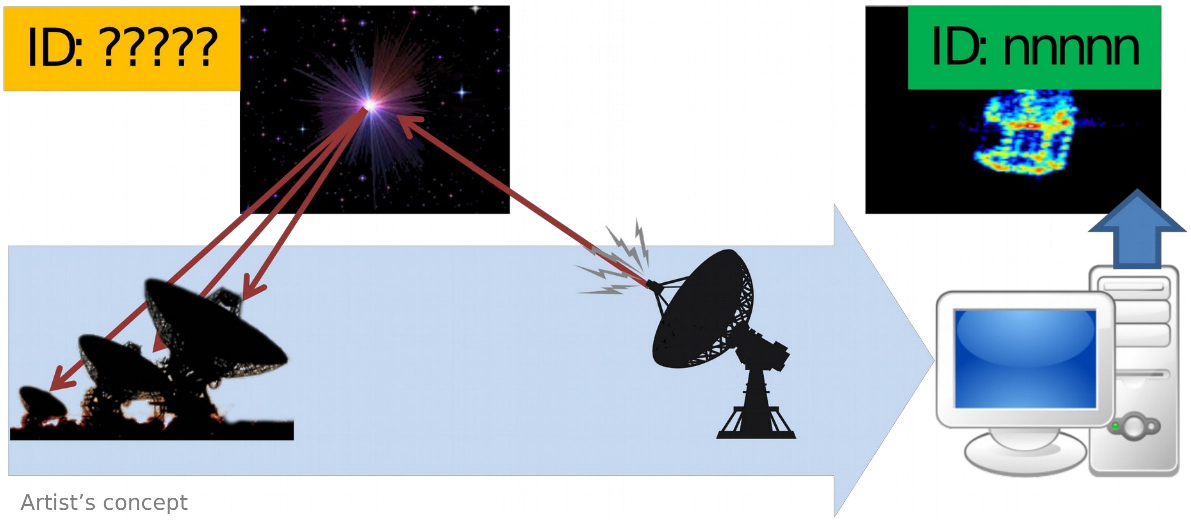
Low-Size, -Weight, and -Power Higher-Performance Software-Defined Radio (SDR) Technology
- Xilinx Virtex 5-based SDR
  - Detailed design and Engineering Development Model (EDM) integration and test (I&T)
- Xilinx Ultrascale-based SDR
  - Initial program kicked off





(Top) (Left to right) Courtesy of SRI International, MMA Design, Harris Corp.
(Middle) Courtesy of FIRST RF
(Bottom) (Left to right) Courtesy of Millennium Space Systems and Trident Systems

RF Imaging of GEO Satellites

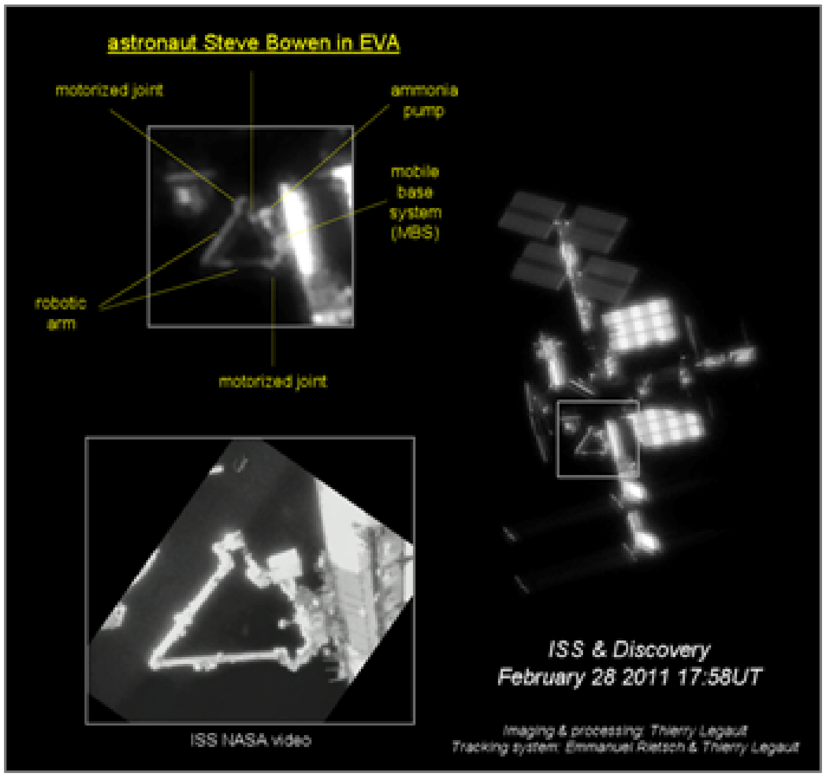


Artist's concept

Purpose:	Key Technologies:	Metrics:
Detect, track and characterize objects in geosynchronous Earth orbit (GEO) from the ground • Day/night all-weather operation • Timely characterization • Satellites continue to decrease in size • High resolution needed to assess anomalies • High resolution needed to characterize objects • Even small pieces of debris pose threats to very expensive satellites • Reduction in cost of large apertures	• Imaging of GEO satellites and other objects is highly difficult due to extreme range > 30,000 km • Flexible, reconfigurable multi-static RF imaging system • Multi-static radar imaging and signal processing, coherent aperture combining, transportable antennas, high gain power amplifiers • Envisioned transition partners: USAF, NASA, FAA, DoD	• Characterize satellites in GEO with high resolution in a timely manner • Characterize debris in GEO in a timely manner

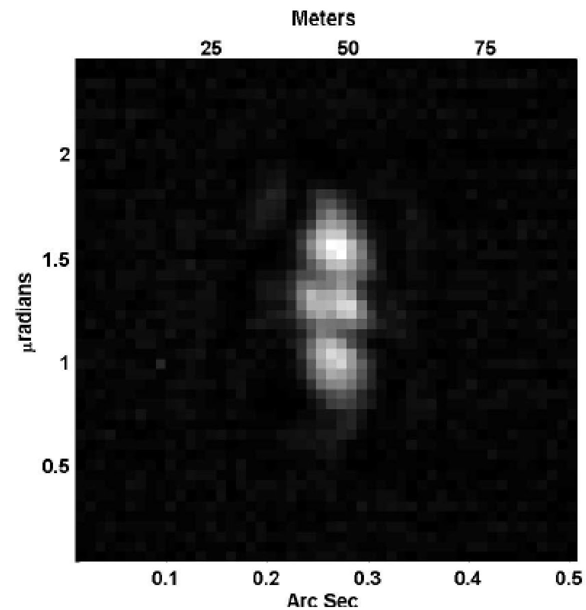
RF Imaging of GEO Satellites Challenges

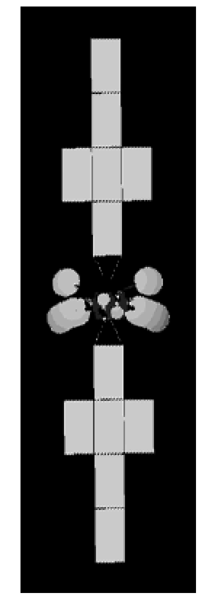
Imaging is routine for low Earth orbit (LEO) objects



Amateur image of ISS spacewalk:
Resolution ~0.5 m

No analogous capability exists for GEO satellites



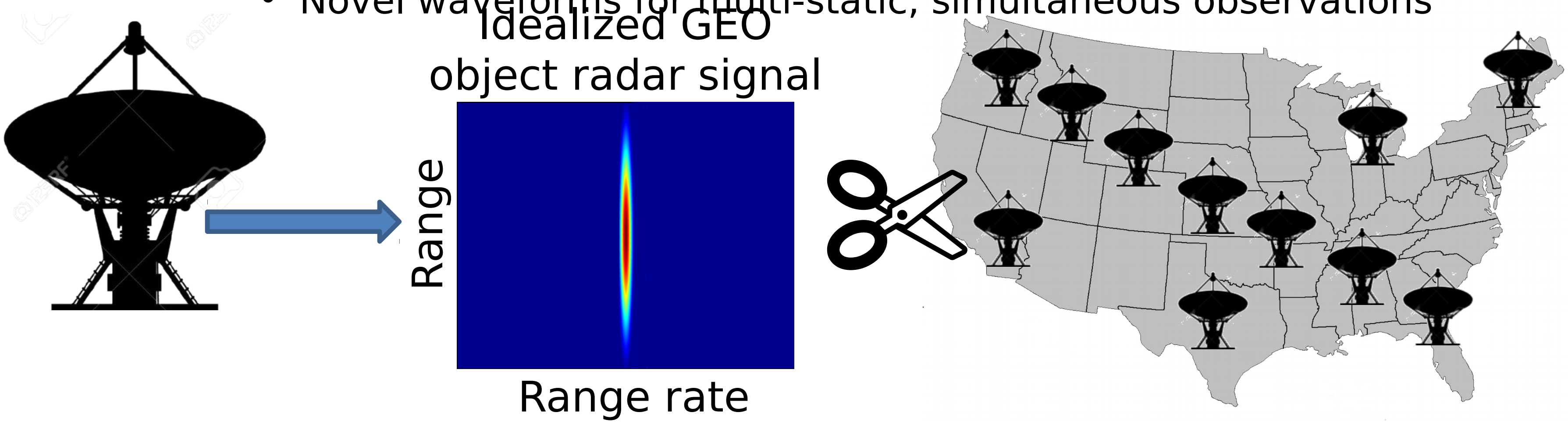


Keck-II image of GE-23
Resolution ~10 m

RF imaging could enable GEO satellite characterization comparable to LEO capabilities

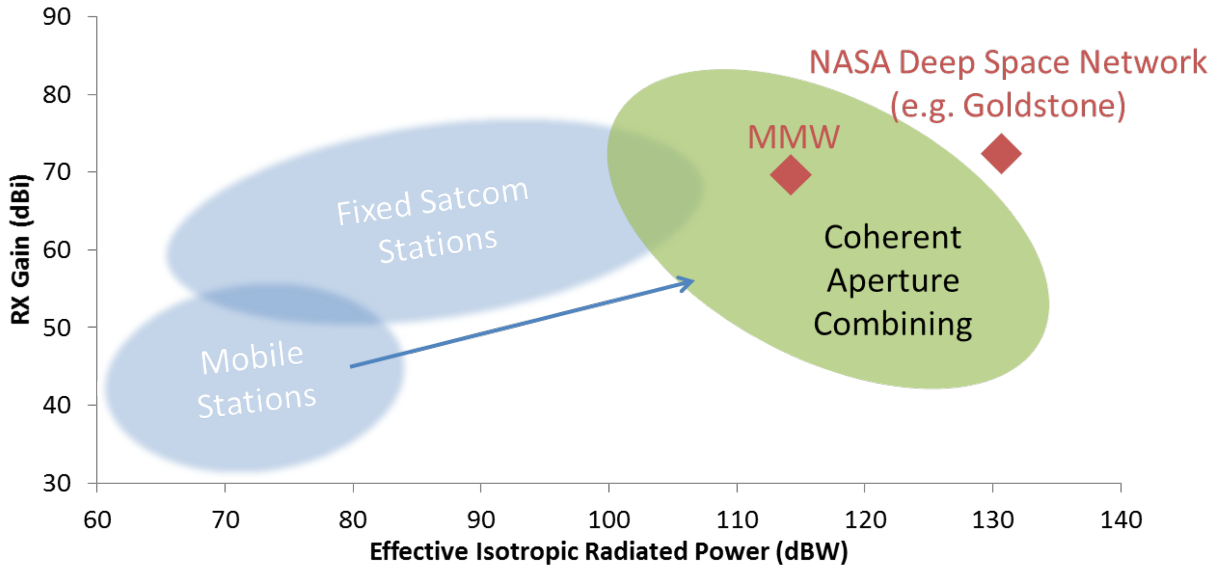
Areas of Interest

- Synthetic Aperture Synthesis:
  - Challenges:
    - GEO objects have near-zero variation in range rate and limited motion
    - Angular diversity required is continental in scale
  - Interest in multi-static signal processing to generate images and minimize the number of apertures, for example:
    - Efficient multi-pulse coherent integration and cross-correlation
    - Tomographic reconstruction methods with sparse angular diversity
    - Novel waveforms for multi-static, simultaneous observations



Areas of Interest and Future Vision

- Coherent Aperture Combining (RX/TX) and High-Gain Apertures:
  - Extreme distance requires high gain/equivalent isotropically radiated power (EIRP)
  - Interest in methods to combine multiple smaller apertures to achieve performance equal to much larger apertures
    - RX phase center location and timing metrology
    - High-efficiency, low-noise amplifier technologies (> 1 kW peak power)
    - Transportable/deployable antennas up to 10 m in diameter
    - Atmospheric phase sensing and compensation



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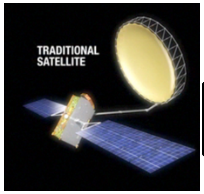
TTO Proposers Day 2016

Dr. Jeremy Palmer, P.E., TTO Program Manager

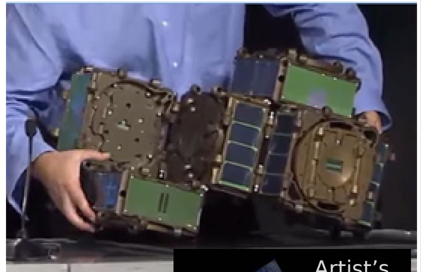
Briefing prepared for TTO Office-Wide BAA Proposers Day

April 20-21, 2016

Phoenix: Satlets and Payload Orbital Delivery (POD) System

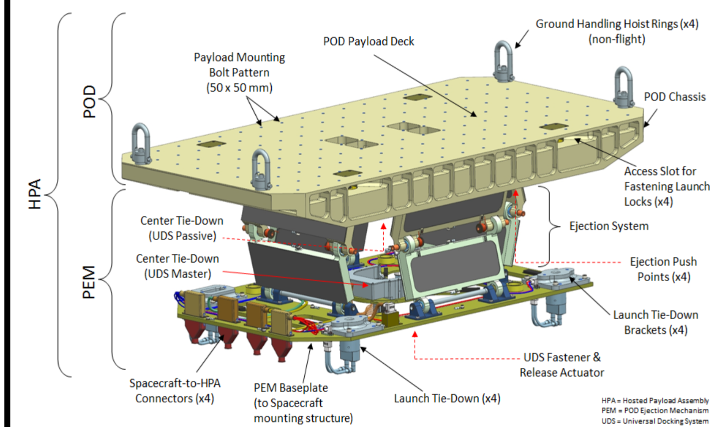


Traditional Satellite



Satlet-Based Satellites

Satlets



Payload Orbital Delivery (POD) System

Purpose:

Satlets:
- Create new space systems at greatly reduced cost compared to traditional approaches
- Change satellite morphology by developing individual "cells" to provide specific functions, either singularly or as aggregated satlets

PODs:
- Establish new mass-delivery route to GEO via hosted and ejected payloads

Key Technologies:

Satlets:
- Cellularized thermal regulation
- Cellularized spacecraft mission manager software
- User-Defined Adapter (UDA) as standard payload interface

PODs:
- Compact Payload Ejection Mechanism (PEM)
- Universal Docking System (UDS)
- Low-mass, high-stiffness chassis for multiple payload items

Metrics:

Satlets:
- Reduced total component costs as compared to a comparable traditional spacecraft
- Reduced timeline from order to unit manufacture to shipment
- Reduced total labor time as compared to a comparable traditional spacecraft

PODs:
- Low tumble rate
- Low trajectory error
- Defined ejection velocity
- Low impulse & force on host
- Low deployment time after command
- Mass: 90 kg (including chassis ~30 kg)
- Volume: 90 cm x 50 cm x 40 cm

eXperiment for Cellular Integration Technologies (eXCITe)

<u>Orbit:</u> 450 km x 720 km, 98 deg

<u>Date:</u> 3QFY16 (scheduled)

<u>Experiment Life:</u> 2-16 weeks

<u>Goals:</u> (First flight of satlets)

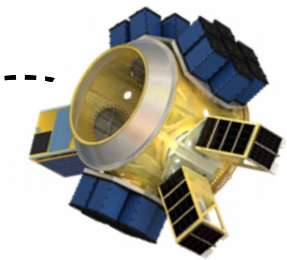
- Aggregated performance
- Adaptation to on-orbit mass changes
- Cellular meshed power
- Cellular thermal management
- Cellular 3-axis attitude control

<u>eXCITe Spacecraft</u> (155 kg):

- Pack of Aggregated Cells (14 HISats)
- Multicore processor
- SeeMe Pathfinder telescope
- R3S environmental monitors
- Radios

eXCITe
(1/2 SHERPA slot)
~ 65 cm x 100 cm x 80 cm

Artist's concept



©Spaceflight Services

SHERPA
(5 payload slots)

©SpaceX

POD-Satlet System Demonstration

<u>Orbit:</u> GEO Transfer Orbit (GTO)

<u>Date:</u> 2QFY17 (scheduled)

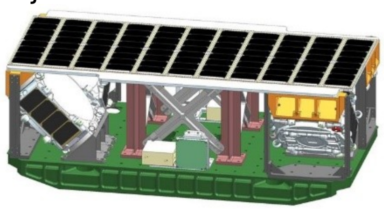
<u>Experiment Life:</u> < 1 year

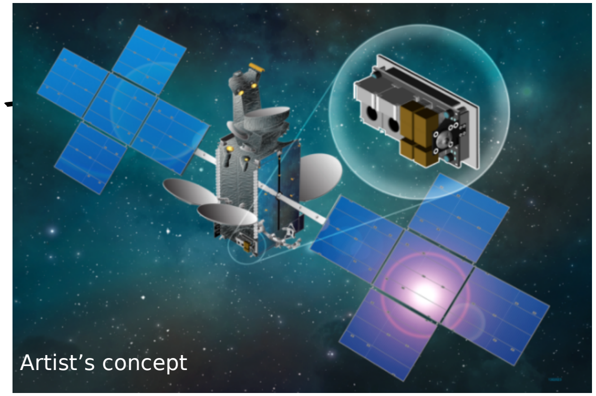
<u>Goals:</u> (First flight of POD, first GTO flight of satlets)

- Safe, controlled ejection of POD from host (expected trajectory, low tumble rate, low impulse on host)
- Data collection over lifetime of satlet system in GTO, passing through high-radiation environments

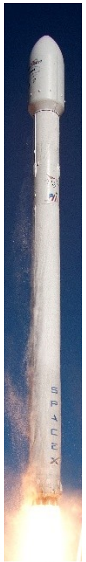
<u>POD-Satlet System Spacecraft</u> (90 kg):
- POD chassis
- Pack of Aggregated Cells (PAC)(4 HISats)
- Radio & antenna

Free-flying POD-satlet system after ejection


Artist's concept

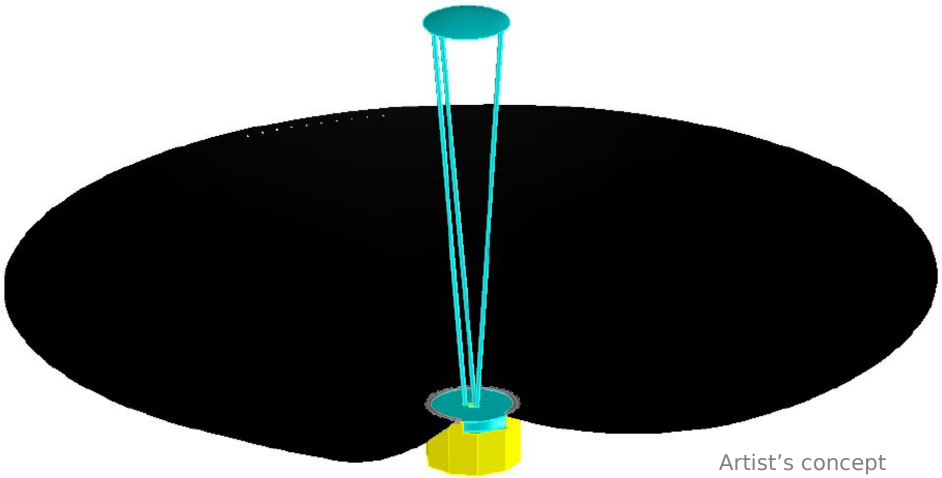


GEO host spacecraft with POD

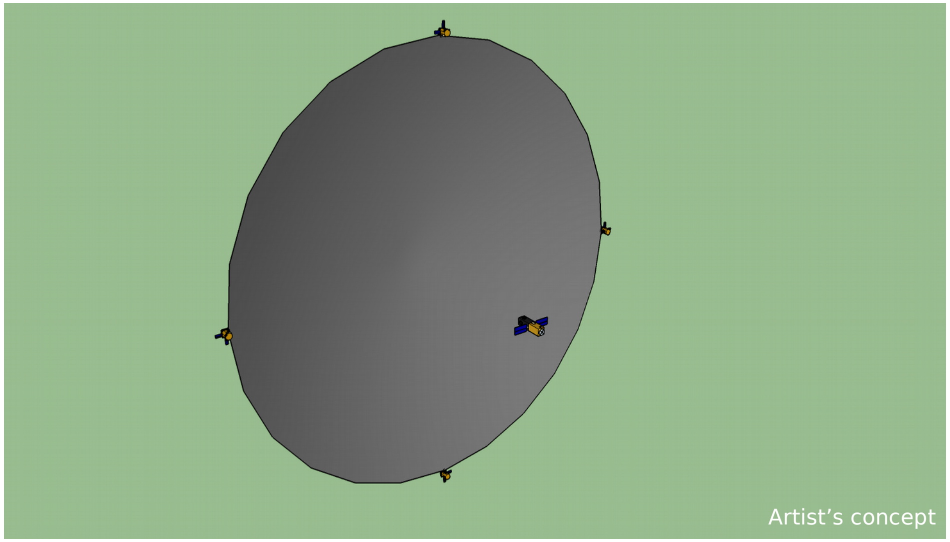


Interest Areas and Future Visions

- <u>Augment</u> a microsatellite after launch with a large *in-situ* manufactured aperture
  - Would allow large RF antennas to fly as ride shares
  - Scalable to realize unprecedented future capability
  - Many approaches:
    - ➢ Assembly of multifunctional modules
    - ➢ Additive manufacturing
    - ➢ Other


Artist's concept

- Revolutionary hosted payloads for high-performance RF milsatcom
  - Lower latency, higher bandwidth
  - Next-gen encryption
  - Reduce co-channel interference
  - Anti-jamming


Artist's concept

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Dr. Gordon Roesler, TTO Program Manager

Briefing prepared for TTO Office-Wide BAA Proposers Day

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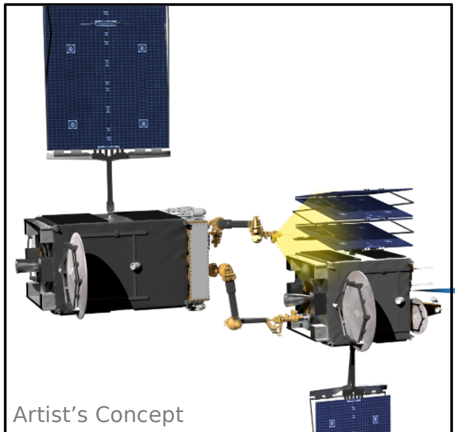
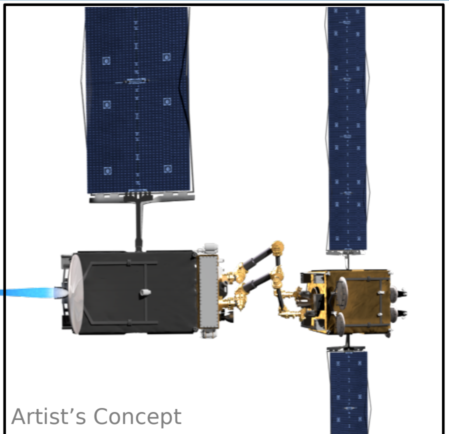
Robotic Servicing of Geosynchronous Satellites (RSGS)



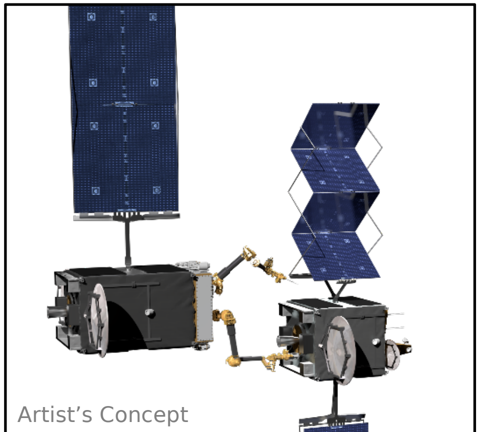
Artist's Concept

Cooperatively **inspect** spacecraft experiencing anomalies



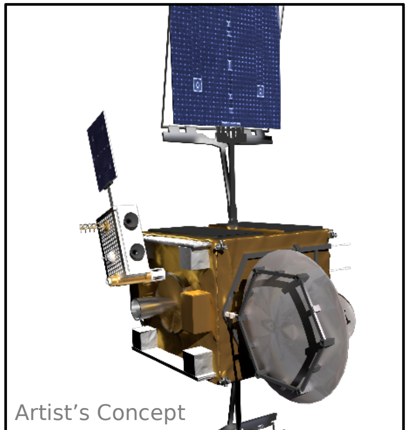
Artist's Concept

Cooperatively **assist** with orbit adjustments



Artist's Concept

Cooperatively **correct** mechanical problems



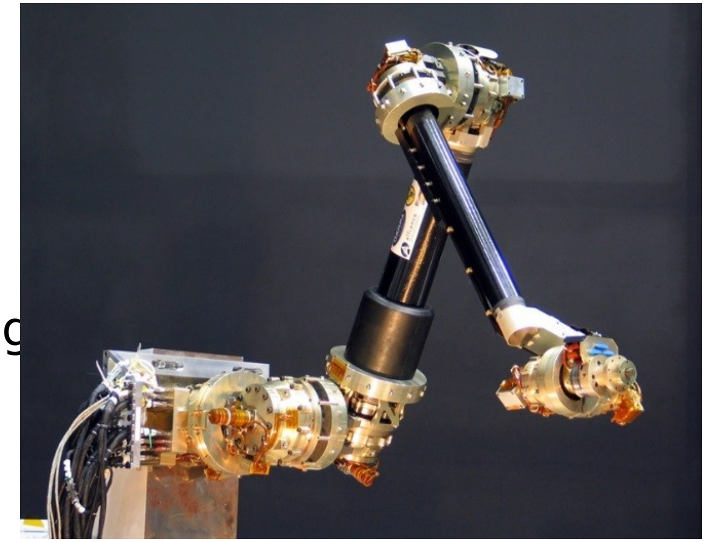
Artist's Concept

Cooperatively **install** self contained payloads on-orbit

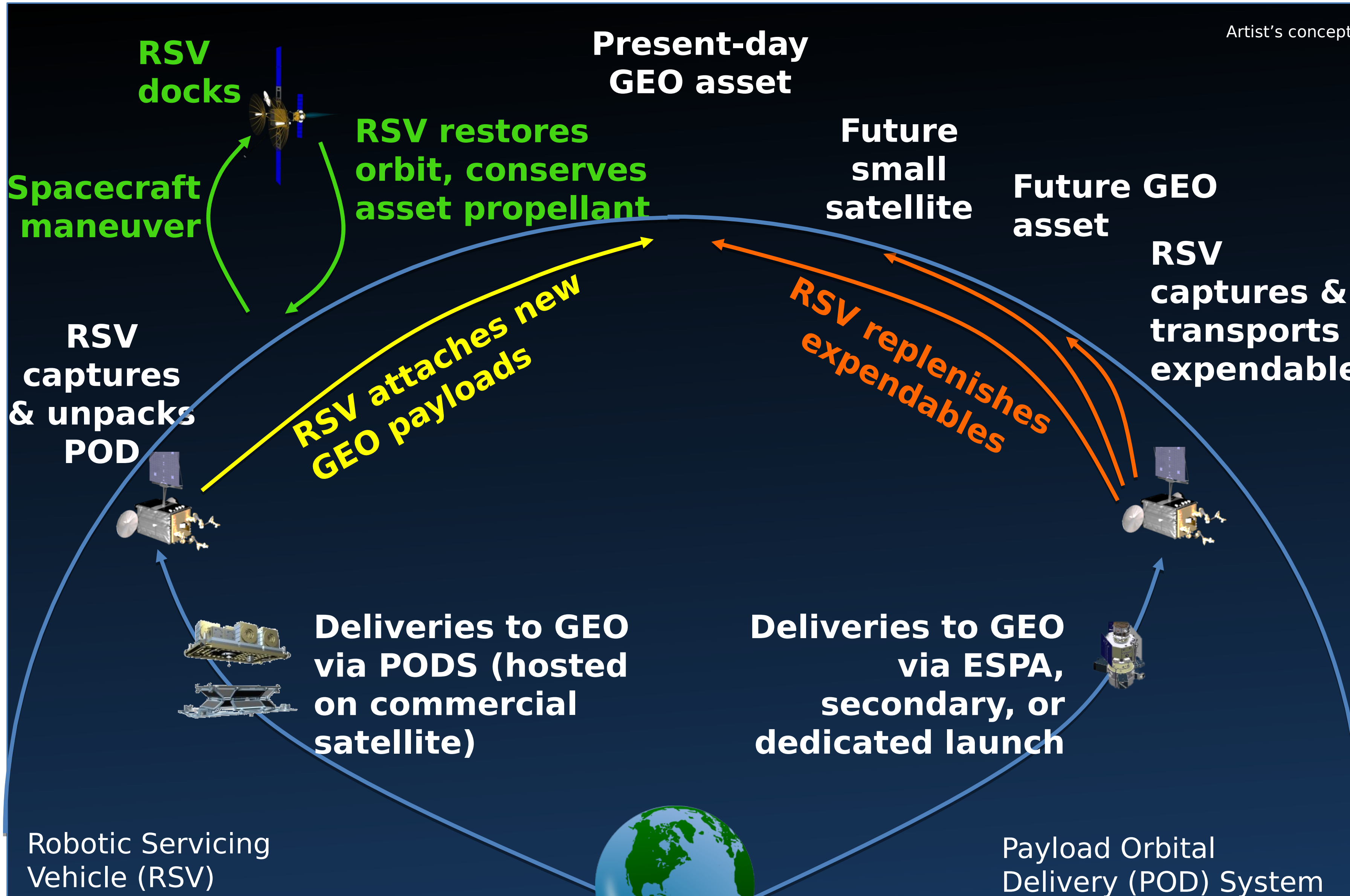
Purpose:	**Key Technologies:**	**Metrics:**
• Dexterous robotic operational capability • Geosynchronous orbit • Increased resilience • Transformed space architecture	• Robotic servicing vehicle • Automated functions • Teleoperation • Simulation capability • POD capture • Interchangeable end-effectors	• Integrated spacecraft readiness • On-orbit demo • Servicing calls • Efficiency

Although Robotics Technologies are Mature, Numerous Technical Challenges Remain

- Verification and validation of software
- Rendezvous and proximity operations
- Bus software modification (retain heritag
- Communications
- Complex control coordination



Interest Areas and Future Visions



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Mr. Todd Master, TTO Program Manager

Briefing prepared for TTO Office-Wide BAA Proposers Day

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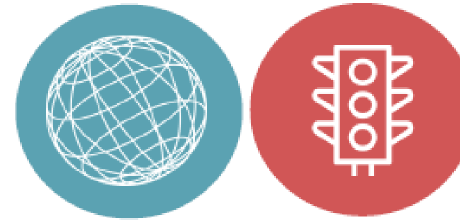
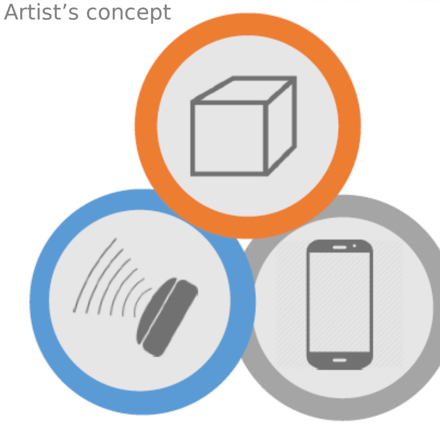
Independent Spacecraft ID Device (ISIDD) — RESEARCH IDEA



- The United States is conducting increasingly advanced space operations, driving needs to evolve and extend domain knowledge
- The government needs to:
  - Improve space situational awareness
  - Enable space traffic management

Artist's concept

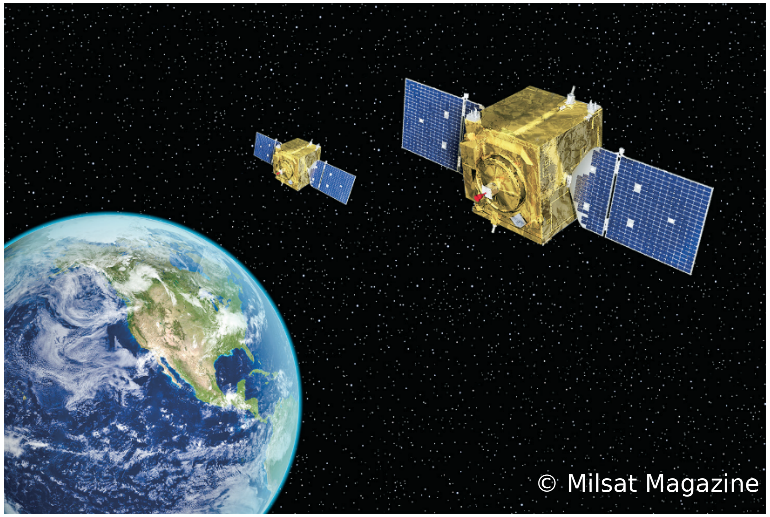
- ISIDD is NOT a current DARPA program
- ISIDD could develop a device that would provide reliable source data about its host space object with low-/no-host requirements to augment external data
  - Respond to interrogation with small but critical dataset of its current state, including ID, position, velocity, and body rates
  - Operate independently from its host, with no power or data interface
  - Designed as a “black box” or distress signal (with sufficient power resources) based on defined trigger events
- Working from current cubesat designs, the proposed goal of ISIDD is to be hosted on all classes of space objects, to include nano- and pico-satellites
- In addition to cubesats, ISIDD could leverage existing smartphone and tagging, tracking, and locating technologies



ISIDD could create a paradigm shift for space domain awareness

Interest Areas and Future Visions

- Standards to support robotic servicing and proximity operations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- Concepts to support space traffic management


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